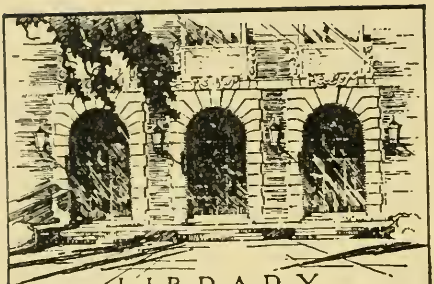

A

PRACTICAL TREATISE

ON

RAILWAYS,

EXPLAINING

THEIR CONSTRUCTION AND MANAGEMENT,

WITH

NUMEROUS WOODCUTS AND TEN PLATES:

BEING

THE ARTICLE "RAILWAYS" IN THE SEVENTH EDITION OF
THE ENCYCLOPÆDIA BRITANNICA,

WITH ADDITIONAL DETAILS.

BY

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PREFACE.

THE substance of the following Treatise has already appeared in the seventh edition of the Encyclopædia Britannica; but as the Editor considered it inconsistent with the plan of that work to insert the more minute details which it embraced, they are here published without abridgment, according to the original design of the writer, which was to give a plain practical account of every subject connected with the construction of a Railway, from the first organization of a Company to the opening and working of the line.

For this purpose, the writer, in addition to his own experience, had the advantage of getting the description of each department throughout the work examined and corrected by gentlemen thoroughly conversant with the subject, they being themselves practically engaged in railway undertakings, principally on the Liverpool, the Birmingham, and the Grand Junction. This revision invariably took place, except in the notice of original suggestions by the writer, such as the fire regulations, the scientific department, and the store department during the progress of the works, &c.

The instructions in each case have been explained in so full a manner, that it is hoped no difficulty will be found in following them out; and as they have mostly been well tested by experience, they are presented to the public, as containing the best practical method of constructing and working a railway at present known. For this purpose, it was indispensable to enter into numerous details; and these necessarily would have enlarged the matter beyond the size which the plan of the Encyclopædia admitted.

The article, as there printed, contains that portion of the subject which is least liable to change in the march of improvement. Alterations, however, will unavoidably take place to a certain extent in the various machinery and appliances of these important works; and while we are now writing, a completely new and original mode of hanging the bodies of coaches to their under carriages, by springs perfectly different from any at the present time in use, is under trial, and the impression is generally in its favour.

It is also beginning to be admitted in many quarters, that some government regulations are imperatively called for with respect to railways. The nature and extent of these regulations can only be fully developed by time and experience. The safest mode of proceeding, however, will be not to do too much at first.

It is to be hoped one evil will be brought prominently before the Parliamentary Committee now sitting, which is the intolerable expense of getting a railway bill

through Parliament. The immense cost, the various difficulties, and the liability to be thrown out on some trifling and insignificant point totally unconnected with the merits of the question, form such a mass of impediments to success, as almost amounts to a positive prohibition against such undertakings.

But so few railways are at present in actual operation, we have not sufficient experience to refer to, particularly for the mode of working them. It would be proper, however, to provide in all future Acts of Parliament for the construction of railways, that they shall be subject to any further laws which it may be found necessary from time to time to enact for their regulation.

June 10, 1839,

CONTENTS.

RAILWAYS.

In treating of the construction and mode of working railways, we shall confine ourselves principally to those which are intended for the transit of passengers and goods, and which are now opening so vast a field for the improvement of the human race; an improvement, in fact, entering into all the relations between man and man, and which no one, be he ever so sanguine, can venture to fix a limit to.

From the middle of the seventeenth century various contrivances have been in use for decreasing friction on roads, particularly near the collieries in the north, such as laying down tracks of wood and stone for the wheels of waggons; it having been found that the much greater quantity of work performed by horses on these tracks, or, in other words, the less number of horses required to do a given portion of labour, more than repaid the expenses attendant on forming the tracks. These, in general, gave way to the flat or tram rail, made of iron; but the improvements were very slow, and at last were only applicable to certain circumscribed localities and materials for carriage.

Possessing little general interest, and chiefly benefiting individuals, the attention they attracted was principally confined to the parties immediately connected with them. But how different is the prospect now before us, since we have

seen the magnificent creations of George Stephenson? Pack-horses are still the only mode of transit for traffic in many parts of the world; and within seventy years this was the general mode of conveyance for the carrying trade to Yorkshire and Lancashire from the west of England and Birmingham. In the year 1830, when the London and Birmingham railway was projected, the expense of constructing it was stated at L.6000 per mile with one line of rails, which were to be worked by horses, and warranted to go eight miles an hour; now the public are complaining of going *only* twenty miles an hour, and we have a right to expect that, at no very distant period, this velocity will at least be doubled; in fact, at the rate improvements have been advancing for the last few years, we know not where to place a limit of increase in speed.

It is of these splendid creations that we have here to speak. We shall shew the method of conducting a modern railway, from its earliest commencement, through all its various stages in each department, both in and out of doors, up to the period of its final completion; and shall end by explaining the method of setting it in full operation, pointing out, in each division of the labour, those modes of proceeding which will most conduce to a satisfactory result, and marking those things which practice has shewn should be avoided; collecting the contrivances and appliances which have been found useful, from whatever source they may be derived, and setting a beacon upon shipwrecks, that they may become other men's landmarks.

When a railway is proposed between any two places, the public want to know how to distinguish between a bubble speculation, got up by a few interested individuals, a crudely-formed and hastily-adopted, but really good project, and a line got up with care and attention through all its parts, shewing it to be the result of patient research and of matured judgment; and according as inquirers find the following directions more or less attended to, they may place confidence in the scheme which is laid before them.

These undertakings generally begin with a few individuals interested in the line of railway proposed, when the project is honestly intended; but the great mass of original proprietors are men of a speculative and adventurous turn of mind, who enter into these concerns for the mere purpose of making money. If the thing succeeds, and the shares rise to a large premium, as they often do, the original holders realize the profits at once, by selling out, and then apply their surplus capital in other projects, with the same hope of gain. These people, by going out, make way for another class of proprietors, namely, those who look to their shares as a permanent investment, and hope to make by them a greater annual receipt than they can get in the public funds, or by any other means.

In the earlier stages the directors are generally self-elected. They should be men of local interest, rather than the lions who are too often found in these situations; men who can influence members of Parliament in either house, conciliate landholders, get off the shares, &c., and, above all, they should be of regular and businesslike habits. After a few meetings, they will find out what are their respective qualifications, and can allot themselves into sub-committees accordingly; some to look after the traffic, others the surveying, others the share list, others to attend to the canvassing along the line, &c. Almost their first duty will be to choose the secretary, the engineer, the solicitor, and the banker.

On the appointment of the first three much of the future success of the company will depend. The secretary should be a man of firmness and nerve, with conciliatory and gentlemanly manners; of a strong habit of body, able to rough it out in travelling, and possessing a stock of scientific and mechanical knowledge. If he is a draughtsman so much the better, and he should have been habituated to command large bodies of men, and be able to make a public speech at a short notice. With these qualifications, habits of order, and plain common sense, he will be a most valuable man.

The engineer must be judged of by the works he has executed, either by himself or under the direction of a superior; the first, of course, being the most conclusive, but the second by no means to be neglected. Skill and genius may often be very prominent in subordinate situations. Of course, all other things being equal, one who has been employed on railways should be preferred to one who has not. The solicitor should, if possible, have been connected with a railway bill before, and should have not only ability, but zeal. The advantage of having one who had been connected with a previous undertaking is obvious, and if he has had much experience in parliamentary business, so much the better; a local acquaintance amongst the landowners and residents along the line is also of much use.

We suppose that, prior to advancing even thus far, the promoters of the undertaking have travelled between the termini of the intended railroad, and have ascertained that there are no engineering difficulties of a marked character; and from our present stage, if the share list be found to fill, we have next to ascertain the nature and quantity of the traffic, first, as to whether it will pay for a railroad at all, and secondly, for what kind of a railroad. These questions should be met openly and honestly, or the consequences will be most disastrous.

The proper way to gain a correct knowledge of the traffic along any given line of country is, first of all, to station a man by day and another by night for two or three weeks, to count all vehicles passing a given number of spots along the intended line, (these spots should be near the principal towns), leaving out the largest terminus, as, for instance, London, and keeping the men on that side of all the respective towns which is nearest the largest terminus. For this purpose memorandum-books should be furnished them to note down all that passes. These should, at the end of their twelve hours' beat, be digested into printed forms, where each class is to be placed in its proper column, and any re-

marks made, if necessary. The forms are then to be daily transmitted by post to the secretary, who should make it his business to ascertain that, by fairs, races, elections, or any other causes of local excitement, the traffic is not in an unusual state. He is then to consider attentively the returns he has received, discriminating that which would be available for the railway in question, from that which would not, and bring the whole series into one general total, under the head of "direct traffic." The men are also to make a return, as nearly as they can, of the number of persons travelling in each vehicle, the quantity of goods in each waggon, van, cart, &c., distinguishing the nature of it, when practicable; also the number of all kinds of cattle passing the road, and where all the various passengers and goods are being conveyed to, as far as can be ascertained.

A similar series of observations must be carried on along the canals, if any, which lead from those parts of the line likely to become available for the intended railway, distinguishing the nature and quantity of the traffic. Most canal-boats are marked at the head and stern with the draught of water; and by finding out what they sink for every half-ton, a sufficiently near estimate may be found of the weight they carry. In certain situations the entries at the custom-house will be useful auxiliaries; the returns from clerks of markets will often materially assist as checks, as will also the rental of the various turnpikes; and no means are to be neglected to obtain a fair and honest statement of the general traffic in actual existence along the proposed line.

The next object is to find out what will be the probable increase on this existing traffic, when it shall be carried so much quicker and cheaper by a railway. The usual method of doing this has been to assume some ratio of increase, deduced from other undertakings of a similar nature, and two to one have been considered rather under than over the truth; but when it is remembered that the increase of passengers, these being the main contributors to a railway, has been, in

all proportions, up to eighty to one, it is obvious that this is a very uncertain mode of ascertaining such an essential element.

A much better method of arriving at this point will be to take, with the help of a map, all those stage-coaches which run from places where travellers can go cheaper and quicker by the proposed railway. The numbers of these, their daily journeys and their mileage, can be readily got from the stamp-office returns, printed in Robson's *Directory*. When these various returns and data of every possible kind have been collected, and information has been brought to bear from every quarter whence it can, by any means, be obtained, the whole must be drawn up ready for calculation, so as at last to exhibit, in the simplest manner in which it can be shewn, a tabular result not only of the existing traffic, but also of that which can be affected by the proposed railway under any circumstances, which latter may be called "contingent traffic."

The best mode of computing the data, as above described, is to multiply the distance between the stations by the number of coaches; then by the number of daily or weekly journeys made by each; and then by the number of passengers they may fairly be presumed to carry. By proceeding in this manner, the last results, in this case, can be added in a column, which will give the number of passengers carried one mile, daily or weekly, as the case may be. This, divided by the number of miles there will be on the intended railway, and augmented so as to exhibit the yearly quantity, will give the first step in the inquiry. The same method exactly is to be made use of for the canal traffic, if any, substituting tons for passengers, which is also to be done with the waggons, vans, and other public conveyances.

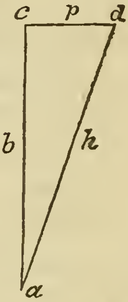
The contingent traffic, or that which is obtained from the stamp-office returns, is to be handled in a similar manner, only taking care that the various coaches and other vehicles are only taken for that distance which, in all pro-

bability, they will go upon the railway. When the whole is reduced, it must be put into money, and will then contrast with the amount of the same quantity of traffic at existing prices.

It is very easy to determine a limit beyond which none of this contingent traffic will, by any possibility, be available for a railway. We shall shew how this is done, as it may serve thus far as a guide, so that no place beyond the limit need, of course, be paid any attention to.

In any triangle *a*, *c*, *d*, (fig. 1), let (*ad*) represent any increment uniformly generated with any given velocity (*h*), and let (*ac*) and (*cd*) represent any other increment uniformly generated with any other given velocities (*b*) and (*p*). Now all these velocities being in this case comparable with each other, if we represent the different increments by the times in which they are generated, we may shew by the respective portions (*ad*) (*ac*) and (*cd*), the progress of any object whose motion is uniform.

Fig. 1.



Let (*ad*) represent a part of the road now used between any two towns (*a*) and (*d*), let (*ac*) be a portion of a railroad, and let (*cd*) be a cross-road joining the railroad (*ac*) with the turnpike road (*ad*). Then if the velocity (*b*) (*p*) and (*h*) in the respective times (t'') (t') and (t) are such, that.

$$t''+t' \angle \text{ or} = t$$

the point *d* would be at the limit, and no person beyond it could travel along (*dc*) and (*ca*) in order to get from (*d*) to (*a*) with advantage.

As a railway may, in general, be taken in comparison with a coach-road, both as to time and price, in the ratio of 1 : 2, price may at once be excluded from the investigation, and time only taken into account; because those to whom time is an object in travelling, by attending to that alone, will evidently reap, along with it, the benefit of cheapness also; and those to whom price is an object, will, in attend-

ing to time only, gain that advantage, and in conjunction with it, the minimum of price likewise. Particular circumstances may, in a few cases, modify this; but the general features of the comparison will be as above.

Taking, then, the ratio of $p:b=h:b=2:1$, and considering $p:h$ to be a ratio of equality, and that for one hour $h=p=10$ miles, and consequently, $b=20$ miles, or, in other words, that on the railroad (b), the rate of travelling will be 20 miles an hour, while on the direct road (h), and the cross road (p), the rate will be at 10 miles an hour; we have then only to add the whole of the perpendicular (p) to half the base (b), and subtract the same from the hypothenuse (h), which is got from the stamp-office returns for each town, and the remainder, if any, will be the miles gained by travelling over the two sides of the triangle instead of over the third, and if there is no remainder, that particular town is beyond the limits, and will not be benefited by the railway, consequently, it must be rejected from the traffic returns.

It is well there were no railroads in Euclid's days. We do not know what he would have said to our thus making the perpendicular and half the base equal to the hypothenuse; but such is the practical fact in the question we are considering, and this fact has been exemplified on every railway where the traffic can partly be derived from towns right and left of the line, which is the case almost invariably. We shall give a few instances, taken from the traffic returns of the London and Birmingham railway.

It is required to know whether the coaches running from Bedford to London ought to be included in the returns of traffic for the London and Birmingham railway, or, in other words, whether the inhabitants of Bedford would go cheaper and quicker to London, by first getting to the London and Birmingham railway, and then proceeding by that route to London, or whether they had better go by the old direct coach road, and *vice versa*, on their return from London, whether it would be cheaper and quicker for them to go

along that railroad, and then by a cross country coach to Bedford, or continue to use the old road?

The nearest station for the people of Bedford on the London and Birmingham railway, is at a place called Wolverton; from Bedford to Wolverton (p) is 15 miles, to which add ($\frac{1}{2}b$) half the distance from London to Wolverton, which is $25\frac{1}{2}$ miles, and the total $40\frac{1}{2}$ miles, ($\frac{1}{2}b+p$) is the equivalent distance from London to Bedford, *via* the railway; that is to say, by travelling along the two sides of the triangle. Now, in the stamp-office returns, it will be found that the direct road (h) is 52 miles, consequently, either in going to London, or coming from it, the people of Bedford would in each case save $11\frac{1}{2}$ miles in equivalent distance, or 1 hour and 9 minutes in time, besides money. It is clear, then, that Bedford ought to be included in the traffic returns of that railway company.

The same question is proposed as to the town of Hatfield. The nearest station on the railway to this place is at Two-waters, and the distance between them (p) is 10 miles; adding to this ($\frac{1}{2}b$), half the distance from London to Two-waters, which is $10\frac{1}{2}$ miles, we have ($\frac{1}{2}b+p$), the equivalent distance *via* the railroad between London and Hatfield, equal to $20\frac{1}{2}$ miles. Turning now to the stamp-office returns, we find (h) the distance from London to Hatfield by the direct road, is also $20\frac{1}{2}$ miles, and consequently, the two routes being equal, that town ought not to be included in the estimate of traffic.

It is required to know the same thing with respect to the town of Hitchen? Here the inhabitants would join the railway in question at Leighton Buzzard, and we find (p)$=16\frac{1}{2}$ miles, ($\frac{1}{2}b$)$=19$ miles, total or ($\frac{1}{2}b+p$) $35\frac{1}{2}$ miles, whilst (h)$=36$ miles; and there would be a consequent gain of half a mile in distance, or 3 minutes in time.

In the case of Oundle and London, the station where the inhabitants of that town would join the railway, is near Northampton, and we have (p)$=26$ miles, ($\frac{1}{2}b$)$=32$ miles,

total or $(\frac{1}{2}b+p)=58$, whilst, by the stamp-office returns, we have $(h)=81$ miles; consequently, there is a gain of 23 miles, or of 2 hours and 18 miuutes, by thus travelling over two sides of the triangle instead of the third.

It is desired to know, whether the inhabitants of Leicester, in their communication to and fro with Birmingham, and *vice versa* those of Birmingham in the communication with Leicester, will be benefited by the London and Birmingham railway. Here the point where each party would either join or leave the railway would be Coventry, and we have $(p)=25$ miles, $(\frac{1}{2}b)=9$ miles, total or $(\frac{1}{2}b+p)=34$ miles, whilst $(h)=36$ miles, shewing a gain of 2 miles, or 12 minutes in time.

We will throw a few more examples into a tabular form, as this part of our subject is a very important one, and cannot be too well understood. Care will, of course, be taken, that all the distances are those really existing on the respective roads in question; and it will also be advisable to re-

Between what places.	Place where the railway would be joined or left.	Distance to or from that place and the required town or (p).	Half the distance from London to the point of junction with the railway, or $(\frac{1}{2}b)$	Total equivalent distance, or $(\frac{1}{2}b+p)$.	h	Gain in miles.	Gain in time. H.	Gain in time. M.
Shenley Hill and London	Watford	7	7	14	17	3	0	18
St. Neot's and London	Blisworth	26	27	53	57	4	0	24
Uxbridge and London	Stanmore	$5\frac{1}{2}$	$5\frac{1}{2}$	11	17	6	0	36
Woodstock and London	Stoney Stratford	25	25	50	64	14	1	24
Stamford and London	Rugby	40	$42\frac{1}{2}$	$82\frac{1}{2}$	89	$7\frac{1}{2}$	0	45
Oxford and London	Fenny Stratford	27	22	49	58	9	0	54

ject all minute savings from the traffic returns, in order to be under, rather than over, in the estimate.

The best way of commencing to make out the following table, will be to take a map of the railway for which it is to be formed; and this should embrace a considerable portion of the adjoining country. Draw on the map a straight line from the one terminus to the other; this will represent (b) in fig. 1, and from this, lay off at right angles from each of the termini, other straight lines; these will represent (p) in fig. 1. We shall now shew how to ascertain the point in (p) from which (h) is to be drawn in each case to the more distant terminus, and then shew the mode of using this figure when thus laid down on the map.

We have given to us by the conditions of the problem.

$$h = \frac{b}{2} + p, \qquad (1)$$

$$p = h - \frac{b}{2}, \qquad (2)$$

$$b = \frac{h-p}{2}, \qquad (3)$$

and from the relations of a right-angled triangle we have

$$h = \sqrt{b^2 + p^2}. \qquad (4)$$

Substituting in this latter expression the value of (p) from equation (2),

$$\text{we get } h = \sqrt{b^2 + \overline{h - \frac{b}{2}}^2},$$

$$\text{whence we have } h = \sqrt{b^2 + h^2 - hb + \frac{b^2}{4}},$$

$$\text{or, } h^2 = b^2 + h^2 - hb + \frac{b^2}{4},$$

$$\text{whence } 0 = b^2 - hb + \frac{b^2}{4},$$

$$\text{or, } hb = b^2 + \frac{b^2}{4};$$

$$\text{and finally, } h = b + \frac{b}{4} = \frac{5b}{4} = 1{\cdot}25\, b,$$

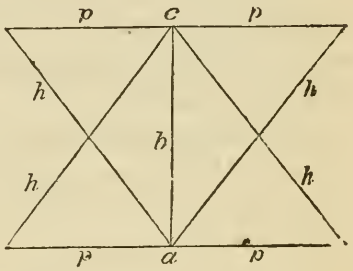
and substituting this value of (h) in equation (2),

$$\text{we have, } p = \frac{3b}{4} = 0{\cdot}75\ b.$$

From this we see, that the length of (p) will always be three-fourths of (b), and the length of (h) once and a quarter that of (b).

On the map then, calling (a) (c) the termini, we set off on (p) in four directions three-fourths the length of the straight line (b), and then draw the four lines (h), (see fig. 2,) and we are sure that the four triangles (b, p, h,) include every town that can by any means come to our termini to use our whole line, and if the line b was in reality a straight one on the ground, as it is in the figure, the triangles would include every other town throughout the whole tract of country, the inhabitants of which could avail themselves of the benefits of the railway, therefore, in using our figure, we must make the outer boundary lines (h), respectively curve right or left as the line of railway departs in either of those directions from the straight line (b). The values of ($\frac{1}{2}b$) may then be found and marked ready for use, as nearly as can be judged, by seeing where the stations would, it is presumed, be ultimately placed; then having ascertained the values of (p) and (h) from the stamp-office returns, or any other equally authentic document, they may in each case be marked against the roads for all the towns which we may see fit to calculate upon for putting or not into the traffic returns, according as their inhabitants would gain or not by using the railway.

Fig. 2.



It will, on a very slight inspection, be self-evident, that for perhaps three-fourths of the whole space included within

the lines (p) and (h), there will be no need of any calculation, except to shew the quantity of saving. In the earlier stages, therefore, if it is merely required to know the amount of traffic ; but only the doubtful places need be computed, and the rest may be deferred till it is desirable to complete the whole table. It must also be noted, that although a place may be actually without the boundary lines, yet there may not be a conveyance from it to either of the termini, as the case may be, and that the inhabitants, in order to be enabled to travel thither, may have to come to a place within the lines. They are then to be tried for as if they were themselves situated within the lines, and, of course, all towns beyond the termini must benefit, when travelling towards the opposite end of the line.

The effect of railways will be this : They can only be made upon main lines, because such lines will alone pay; the stage coaches will go off these lines when the railway has been a short time in operation, but the same coaches will be employed on cross country roads to feed the railway ; and it is a curious fact, that through this operation one more coach was licensed at Liverpool and Manchester the year after the railway opened than there was the year before.

If the above rules be attended to, a tolerably correct knowledge of the traffic to be expected may be obtained, and it is sure not to be an exaggerated one. Whilst this has been going on, the engineer will have been employed in looking at the general features of the country preparatory to surveying and levelling it ; and in most cases a man of a practised eye at this kind of work will be able at once to decide on all the principal points along which the line should go. During the same time the solicitor will have been feeling his way amongst the landowners and the occupiers, so that where much dissent is manifested, that property may if possible be avoided. Landholders have been proverbially hostile to railways, and enormous in their demands for compensation, yet they have invariably found that their property has been benefited in-

stead of being injured; and when more land has been required from them, they have asked a higher price on account of that very railway running through their property, whose existence they had in the first instance declared to be a nuisance. This state of things cannot last much longer; but whilst it does, it must be met as far as possible in the above manner.

There are many things to be taken into consideration before definitely fixing on the precise line in which a railroad is to run. Borings should be largely taken to obtain a correct geological knowledge of the various strata. A consider able subsequent expenditure may often be saved in this way. It is of no use to put a penny on our eyes to hinder us from seeing a guinea. Borings may be carried to any depth by sinking a well part of the way, and without this they have been worked to a depth of 760 feet. The nature of the traffic must also be taken into consideration, so that when all other things are equal, the line may be run so as to include particular towns. The population of all the adjacent places should be ascertained and marked on a map; the nature of the various markets and fairs should be examined into and the state of trade; the wants of persons connected with it ought also to be taken into account; the quantity and quality of the existing goods traffic, its nature, and the demands on it with reference to any probable increase; and the capabilities of harbours, if any are within reach of the line, their draught of water, the nature of the protection they afford, their present trade, and the effect of the railroad on that trade. In this, as well as in all other cases, the results of a transition from peace to war, and *vice versa*, should be well considered, together with the effect of any future line of railway which may become a partially competing one.

The more effectually these inquiries are made, and the more fully their results are honestly put before the proprietors, together with separate estimates for the engineering department and the managing department, so will their confidence in the undertaking increase; and it is a most essen-

tial point to place this confidence on a sure basis, so that if any little mishap, which none can avoid, take place, the shares may not be suddenly thrown on the market at a ruinous sacrifice, and the undertaking abandoned, through the projectors not having had the necessary information, to enable them to see that the result of their labours would be a profitable speculation, notwithstanding any trifling losses arising from causes against which perhaps no human foresight could provide.

Railways with two lines of rails in very favourable situations have been completed for L.10,000 per mile in England. This however must be taken as the exception, and not the rule. Under very unfavourable circumstances they have cost L.50,000 per mile; and of course there will be found an expense per mile at all differences between these two, which may fairly be taken as the extreme limits. Now it is certain, that with a line 80 miles in length, a traffic of 75 tons of goods per day from each end, or 120 passengers per day each way, or with 35 tons of goods and 60 passengers per day each way, the railway, if even constructed for L.12,000 per mile, which will rarely happen, would not afford a dividend of more than a quarter per cent, and (our numbers throughout meaning daily each way) it would require 100 tons of goods, or 160 passengers, or 50 tons of goods and 80 passengers, to pay 1 per cent.; 125 tons of goods, or 200 passengers, or 62 tons of goods and 100 passengers, would but little exceed $1\frac{3}{4}$ per cent.; and it would take 200 tons of goods, or 320 passengers, or 100 tons of goods with 160 passengers, to pay $4\frac{1}{4}$ per cent.

The Americans have such facilities for these constructions, that 1600 miles of railroad have been made in that country (a good deal of it, however, being only single line) at an average cost of only L.5081 per mile; whereas in England the mere permanent way alone would amount to L.4400 per mile, if the rails were 45 lbs. to the yard, and laid upon longitudinal timbers; L.4900 per mile, with rails 42 lbs.

per yard, having chairs and cast-iron supports between them, on longitudinal timbers; L.5300 per mile, with rails 42 lbs. per yard, on blocks 3 feet apart; L.4800 per mile, with the same sized rails on wooden sleepers; L.5600 per mile for 62 lb. rails, on blocks 4 feet apart, and L.5100 for the same rails on wooden sleepers; L.6000 per mile for rails of 75 lb. per yard on blocks 5 feet apart, and L.5500 per mile for the same on sleepers. These prices do not include laying the way, ballasting, and draining. Thus we see that the mere cost of the permanent way in the country, averaging L.5200 per mile, exceeds that of the whole expense of a complete railway in America; and 75 pound rails on blocks and sleepers, including laying, ballasting, sidings, turnplates, and every expense, has exceeded L.8000 per mile.

The mean receipts for five years on the Liverpool and Manchester line give the following proportions: Revenue 100, expenses 55, profits 45; and the expenses have been as high, or higher than 60. The average, however, gives the ratio of revenue to profit at 1 to .45. On the Dublin and Kingston railway the same ratio for 26½ months gives 1 to .4344. On the Brussels and Mechlin railway the ratio for 1 year is 1 to .488. On the Grand Junction railway, for 6 months, it is 1: .48. On the London and Birmingham, no data exist to form a judgment. There is a very singular coincidence in these ratios on lines so very differently circumstanced, and of lengths varying from six miles to more than 100; but we have not yet acquired any sufficient experience in railway statistics to enable us to speak with confidence on the subject. If every railway would publish yearly its experience, as was so handsomely done in the Liverpool and Manchester for several years, analyzing every source of expense, and reducing them to the ratio per passenger and per ton per mile, we should then soon acquire such a stock of knowledge as would enable all these points to be decided; indeed, of so much consequence are railways now becoming, that the legislature should take up the question, making it a law that returns

should be sent yearly, according to a form arranged by some person thoroughly conversant with the subject.

When matters are so far advanced that the engineer can be directed to make out his plans and sections, he will commence by consulting the ordnance map, and by the help of that and his geological knowledge, obtained from the borings and trial shafts, together with his inspection of the wells, mines, quarries, and other excavations in the immediate vicinity of the intended work, he will proceed to lay down at least three or four lines, if some local circumstances do not absolutely limit him to one particular tract of country; endeavouring to cross all streams and rivers as near their source as possible, that being the lowest point; and where hills intersect his progress, aiming at some position where streams run down on either side in the direction as near as possible to his intended line. He should avoid going along the sides of hills, particularly if they are composed of clay or shale, in order to be clear of the unpleasant consequences which slips would give rise to in these strata. He should run through no more seats or ornamental pleasure grounds than possible, and avoid towns and villages where the land would be expensive. He should, as far as practicable, be furnished with lists of the population, the state of trade, and the numbers of the assenting and dissenting owners and occupiers of land, together with the quantity and value of their property. He should have the water analyzed with reference to its fitness for locomotive engines, inquiring into the state of the existing roads and canals, as to the facilities they afford for getting coke, building materials, &c. on to the line; also whether lodgings can conveniently be had for large bodies of men, and whether the necessary labourers and mechanics can be procured at reasonable rates in the immediate vicinity of the line; and generally he should enter into all inquiries necessary to enable him to choose the best line, and construct it at the least cost.

In order to save time and expense, it will be quite suffi-

cient if what are called rough or flying levels are taken of these preparatory lines, for which purpose the mountain barometer will be amply sufficient, if proper care be taken to apply the necessary corrections, and strict attention be paid to comparing it as often as possible, and at stated regular times, with a stationary standard barometer. Cross stations between the lines should likewise be taken, in order to ascertain the lowest point. The rates at which streams run will also assist in giving indications, and the ordnance map may be sufficient authority for distances. He should particularly attend to curves and gradients; a curve of three-quarters of a mile radius, in conjunction with a rise of 16 feet in a mile, reducing the speed of a locomotive to nearly one-half. Where the gradient is good, curves are not of so much consequence. A curve of a quarter of a mile radius on the Bolton and Leigh railway is constantly passed with safety at a speed of thirty miles an hour, but the wear of engines and carriages must be increased.

The whole question of gradients is only beginning to be understood; and we have no doubt that at some future time railways will be made much more level than they now are. There is no reason why in many cases hydraulic locks should not be used to carry the trains up and down different levels, and to do away with the inclined planes. The practical effect of gravity is not well known. We have long had the angle of repose given as 1 in 280. This is correct with some carriages and waggons, but others differ extremely. Care must be taken where two planes meet that they are eased into each other if their difference is much. This is best done by laying a short piece of the line level. We have known an instance in which, at an inclination of 1 in 330, a waggon ran down 4 miles, and acquired a velocity of 8 miles an hour. The question is not at what angle a carriage will just become quiescent, but at what angle will a velocity be acquired which can have a useful practical effect. The Irish railway commissioners have taken this at 1 in 140; whilst

on the London and Birmingham railway the Euston extension plane is for a considerable part of its length 1 in 75, the trains on it attaining a velocity of 30 miles an hour, and working remarkably well. It is unfortunate, too, that their classification of engines does not contain at all, those in use on that line. The third class is the nearest, but will give much too little as the power of those engines, which go 60 miles an hour up considerable inclined planes. The third class has 11-inch cylinders, 18-inch stroke and 5-feet wheels, the weight being, engine, 8½ tons, tender, 5½.

The principal difference between this class and the engines on the London and Birmingham railway is, that the latter have 5½-feet wheels and 12-inch cylinders. Taking, however, the above third-class engine, and allowing the friction of the engine gear to be 51 lbs., the friction of the engine on the railway 68 lbs., the friction of the tender 49½ lbs., and the atmospherical pressure upon the piston 190.06 inches, reduced in the inverse proportion of twice the stroke of the piston to the circumference of the working wheel, or 533½ lbs., we have a total absorbed power of 702 lbs. before the engine can move, or, which is the same thing, a steam pressure of 702 lbs. is requisite for that purpose. Now the whole power being the area of the piston multiplied by the pressure, say 64.7 lbs., when the steam is at 50 lbs., we get for the whole power of the engine 2337 lbs., or the power to propel the load 1639 lbs., which, even with 9 lbs. per ton friction caused by the load, gives a fraction of 182 tons on a level.

Supposing a load of 88 tons, including the tender, on a level, to be drawn at the rate of 20 miles an hour, and that it has to ascend afterwards a plane of 1 in 140, we have then the absorbed power =702 lbs.; 88 tons at 9 lbs. per ton =792 lbs. or 1494 lbs. power of steam pressure required for this load on a horizontal plane. But when the train comes to the inclined plane, the weight of the engine has first to be added, making the load 100 tons, or 224000 lbs., and $\frac{1}{140}$

of this, or 1600 lb., is the additional traction required, and taking every 8 lb. traction to cause 1 lb. additional friction on the engine gear, gives 200 lbs., therefore the whole power or steam pressure required is, up the plane, 3294 lbs., and the velocity being inversely as the pressure, we have 3294 : 1494=20 : 9, or the velocity will be reduced to 9 miles an hour; in other words, the time expended in ascending the inclined plane will be more than double that which would be required on an horizontal plane, but as the descending will be performed in the same time as if it was a horizontal plane, and as 1494 : 3294=1 : 2·2, the equivalent length of the horizontal plane, the length of the ascending plane being unity, will be 2·2, and the average of the two will be 1·6.

It is upon these data the Irish railway commissioners give tables of the lengths of equivalent horizontal lines to gradients from 1 in 90 to 1 in 1500, and as the errors in the

Gradient.	Equivalent horizontal lines.		
	Ascending.	Descending.	Mean.
1 in 90	2·66	1·00	1·83
„ 95	2·58	1·00	1·79
„ 100	2·50	1·00	1·75
„ 110	2·36	1·00	1·68
„ 120	2·25	1·00	1·62
„ 130	2·15	1·00	1·57
„ 140	2·07	1·00	1·53
„ 160	1·94	·83	1·43
„ 180	1.83	·83	1·33
„ 200	1·75	·83	1·29
„ 250	1·60	·83	1·21
„ 300	1·50	·83	1·16
„ 350	1·43	·83	1·13
„ 400	1·37	·83	1·10
„ 500	1·30	·83	1·06
„ 750	1·20	·83	1·01
„ 1000	1·15	·85	1·00
„ 1500	1·10	·90	1·00

data are principally on the safe side, we give here the most useful one for the description of engine we have before stated, the gross load, including the engine and tender, being 80 tons, and the length of the inclined plane being taken as unity.

The following table from Mr. Pambour's work will also assist in forming a judgment; it is for engines of 8 tons, the loads being that of the train and tender. The errors here are also on the safe side.

Load—tons.	Equivalent load on a level, the inclination of the plane being					
	$\frac{1}{500}$	$\frac{1}{400}$	$\frac{1}{300}$	$\frac{1}{200}$	$\frac{1}{150}$	$\frac{1}{100}$
25	44	48	56	71	87	117
50	83	91	105	131	158	212
75	122	133	153	191	230	307
100	161	176	201	251	302	402
125	200	218	249	311	373	497
150	239	261	298	371	445	592

The great disadvantages arising from bad gradients, are capable of being tolerably well estimated by these tables; but the principal evil is the expense which they occasion, since the load to be carried along the whole line must not be heavier than can be drawn by the engines up the inclined planes, or else additional engines must be employed to assist at those places. On some of the American railways, there are planes so steep that sails are made use of in descending them to check the velocity. The Irish railway commission have computed the cost of working locomotive engines with different loads, as in the following table, in which, as in the preceding one extracted from them, the engine may be expected to do more than is stated.

This table, as far as expense goes, can only be considered as an approximation; the steam pressure too, which is taken at 9 lb. per ton, is higher than what is now found to

be the case; but it will, nevertheless, shew the relative expense; for instance, if the engine can draw 191 tons on a level, and there are gradients of $\frac{1}{200}$ on the line of railway, the load, to enable the engine to ascend these, must be only 75 tons, and the ratio of expense will be 1·04—·72= ·32, or the increased cost of the engine will be 32 per cent. on its journey, besides, there being three journeys to carry the 191 tons, so that the expense and locomotive power will be quadruple what it would amount to if the line was level, and double what it would be with no incline beyond $\frac{1}{700}$.

Tons load.	Steam pressure.	Relative speed.	Power expended per ton per mile.	Wages per ton per mile.	Wear and tear per ton per mile.
0	702	2·02			
10	792	1·79	4·46	4·46	4·46
20	882	1·61	2·48	2·48	2·48
30	972	1·46	1·82	1·82	1·82
40	1062	1·34	1·49	1·49	1·49
50	1152	1·23	1·29	1·29	1·29
60	1242	1·14	1·16	1·16	1·16
70	1332	1·06	1·07	1·07	1·07
80	1422	1·00	1·00	1·00	1·00
90	1512	·94	·95	·95	·95
100	1602	·89	·90	·90	·90
110	1692	·84	·86	·86	·86
120	1782	·79	·84	·84	·84
130	1872	·75	·81	·81	·81
140	1962	·72	·79	·79	·79
150	2052	·69	·77	·77	·77
160	2142	·66	·75	·75	·75
170	2232	·64	·74	·74	·74
180	2322	·63	·73	·73	·73

The following table will be useful in calculating gradients:

Table of Gradients.

Feet per mile.	Inches per chain.	Ratio of height to length.	Feet per mile.	Inches per chain.	Ratio of height to length.
1	0·15	1 in 5280	45	6·75	1 in 117·3
2	0·30	„ 2640	46	6·90	„ 114·8
3	0·45	„ 1760	47	7·05	„ 112·3
4	0·60	„ 1320	48	7·20	„ 110·0
5	0·75	„ 1056	49	7·35	„ 107·7
6	0·90	„ 880	50	7·50	„ 105·6
7	1·05	„ 754·2	51	7·65	„ 103·5
8	1·20	„ 660·0	52	7·80	„ 101.5
9	1·35	„ 586·6	53	7·95	„ 99·6
10	1·50	„ 528·0	54	8·10	„ 97·8
11	1·65	„ 480·0	55	8·25	„ 96·0
12	1·80	„ 440·0	56	8·40	„ 94·3
13	1·95	„ 406·1	57	8·55	„ 92·6
14	2·10	„ 377·1	58	8·70	„ 91.0
15	2·25	„ 352·0	59	8·85	„ 89·5
16	2·40	„ 330·0	60	9·00	„ 88·0
17	2·55	„ 310·6	61	9·15	„ 86·6
18	2·70	„ 293·3	62	9·30	„ 85·1
19	2·85	„ 277·9	63	9.45	„ 83·8
20	2·00	„ 264·0	64	9·60	„ 82·5
21	3·15	„ 251·4	65	9·75	„ 81·2
22	3·30	„ 240·0	66	9·90	„ 80·0
23	3·45	„ 229·5	67	10·05	„ 78·8
24	3·60	„ 220·0	68	10·20	„ 77·6
25	3·75	„ 211·2	69	10·35	„ 76·5
26	3·90	„ 203·1	70	10·50	„ 75·4
27	4·05	„ 195·5	71	10·65	„ 74·4
28	4·20	„ 188·6	72	10·80	„ 73·3
29	4·35	„ 182·1	73	10·95	„ 72·3
30	4·50	„ 176·0	74	11·10	„ 71·4
31	4·65	„ 170·3	75	11·25	„ 70·4
32	4·80	„ 165·0	76	11·40	„ 69·5
33	4·95	„ 160·0	77	11·55	„ 68·6

Table of Gradients continued.

Feet per mile.	Inches per chain.	Ratio of height to length.	Feet per mile.	Inches per chain.	Ratio of height to length.
34	5·10	1 in 155·3	78	11·70	1 in 67·7
35	5·25	„ 150·8	79	11·85	„ 66·8
36	5·40	„ 146·6	80	12·00	„ 66·0
37	5·55	„ 142·7	81	12·15	„ 65·2
38	5·70	„ 138·9	82	12·30	„ 64·4
39	5·85	„ 135·4	83	12·45	„ 63·6
40	6·00	„ 132·0	84	12·60	„ 62·9
41	6·15	„ 128·8	85	12·75	„ 62·1
42	6·30	„ 125·7	86	12·90	„ 61·4
43	6·45	„ 122·8	87	13·05	„ 60·7
44	6·60	„ 120·0	88	13·20	„ 60·0

When, therefore, the flying levels are complete for the three or four lines, as we have before directed, the engineer and manager, or secretary, should bring all their information together, and throwing it into one common stock, select that line out of the whole, which, on the fullest deliberation, appears to be the best with reference to its gradients, geology, commercial importance, and the facilities it affords for soundly and cheaply constructing the necessary works. This subject will of course require deep attention, and the reasons for the selection should be written out in the fullest and clearest manner, for the inspection of any proprietor who may desire to see them, publicity always insuring confidence; and in most cases, it would be best to submit vital points of this kind to a general meeting of the whole body, before proceeding to parliament to obtain an act of incorporation. This would entirely prevent any mistrust.

That these matters require the greatest consideration, will be apparent from the difficulty, delay, and expense of obtaining acts of parliament for railways. The cost of that for the Liverpool and Manchester line, for instance, thirty

miles, was about L.900 per mile. That for the London and Birmingham, 112 miles, was L.72,869, or L.650, 12s. per mile; and it is well known that the expense has reached L.1000 per mile on long lines, and that latterly, in every new session of parliament, there have been fresh difficulties thrown in the way of obtaining the necessary acts, till it is now nearly impossible to succeed at all.

There are many very great hardships connected with obtaining an act of incorporation for a railway. Parliament requires that a plan and section of every part of the ground through which the intended line is to pass, shall be lodged with their clerk, and with the clerks of the peace in every county through which the railway goes. This is a very proper regulation, in order that every landholder may be able, by travelling a convenient distance, to have a personal inspection of a duly authorised document, so as to examine the nature and extent of the benefit, or the inconvenience which it may occasion to his particular property; but parliament should at the same time have given the railway companies the power of complying with this wholesome regulation, in the same way as road surveys are made in Ireland, by an order from two magistrates to enter any requisite grounds. This, however, is not done, and therefore it follows, as a necessary consequence, that the projectors of these undertakings, no matter how beneficial or important soever to the community at large, are left entirely at the mercy of the landholders, whether they can make their survey or not. We have ourselves known, that when decided opposition has been evinced to the undertaking, the engineers and surveyors have been put to all possible shifts to obtain the necessary data for their plans and sections. Working by night with lanthorns has even been unavoidably resorted to; and in one case, where the proprietor was a clergyman, he was watched on Sunday until he went into his church, and a strong party immediately set-

ting to work, just succeeded in finishing the business as he concluded his sermon.

The facilities of opposing a bill in parliament are so great, that every temptation is held out to do so, especially when the rich harvest to counsel, solicitors, and witnesses, is considered; and as has been well observed by the Irish railway commissioners, discussions are mooted of the most discursive and discordant kinds, relating to all the abstract professional matter in the most distant manner connected with a railway. The principles of curves and gradients are entered into with mathematical precision, and the laws of friction and gravity are investigated; questions about which the counsel and the court are often equally ignorant, the one side seeking to swell the estimates and lower the profits, and the other pulling in the opposite direction, like the bulls and bears on the stock exchange, till at last, probably after the expenditure of thousands, the bill is thrown out, not on its own merits or demerits, but because, perhaps, a notice to the proprietor of five or six yards of a cabbage garden, was left next door by mistake.

The parliamentary rules are now as much too strict, as they were at first too loose. The time when the required plans and sections are to be deposited, is very inconvenient; two years at least being required between the deposits being paid and the act obtained. Thus, at the present time, if any line is wished to be procured, the surveys must be made in the autumn of 1838, the plans must be lodged and the notices given in March 1839, the petition for the bill presented to the Commons in February 1840, and supposing the act obtained the same session, little if any real work can be done until the spring of 1841. The subscription of ten per cent. required on the capital, merely leads to delusion; bankers in general advance the money, and whether the bill succeeds or fails, they get it back with interest and commission, for by the very terms of the order of the

House of Commons, it may be paid back to the person advancing it. The public obtain no security against a bad project by this regulation, whilst a good one may be crushed for want of a speculating capitalist. Nobody is benefited in fact, except the banker and the broker; and that this is the process largely employed all are perfectly aware.

If a bill be lost in one session, it cannot be proceeded with in the next without a new contract deed being signed. This is a considerable hardship. The deviation in section is too limited, and should only apply to raising embankments and lowering cuttings; the reverse should be allowed to any extent, and the deviation should be reckoned from the surface of the ground, and not the lateral line. If the same line is kept, the effect would be the same, but by removing to a different level, what may be cutting in one respect may be embanking in another. The limitations in all respects as to deviations may be considered as too strict, and they always have the effect of cramping the company and their engineer; palpable improvements in many cases, have been abandoned on account of the heavy cost of going to parliament for new acts; and others in all probability would never have been made, except that the companies in question were forced to apply for a new act, in order to enable them to borrow more money, and then the improvement is put in along with the rest as a rider.

When the intended line is once decided on, the surveyors should be sent out as speedily as possible; and these are followed by the levellers, who are the engineers. It will be best to survey wide, when you are not quite certain of the exact position of the line; the surveyors give in their plans to the engineers, who proceed to lay down upon them the line as their levelling goes on, taking care as nearly as possible to balance the cuttings and embankments. It will save the engineers a deal of trouble, if, where curves are to be run, a man is sent a-head to put in marks at short distances, giving him the measure from the nearest hedge on

the plan, which measure he takes on the ground, and sticks in his mark.

It will be best to take ground enough to make the embankments sufficiently wide ; if this is not attended to, when they come to shrink, as they undoubtedly will, they become too narrow, and an addition has to be made to their width, which will be found a very troublesome operation, such additions being peculiarly liable to slip.

The survey, with complete plans and book of reference, containing the land for at least three times the width required for the railway, shewing every field numbered for each parish, with its owner and occupier, ought not to cost more than L.15 per mile. The best plan will be to survey as wide as is intended to apply for a power of deviation in the act of parliament.

The next thing is for the engineer to make out his detailed estimates, and get ready his plans and sections to be deposited in parliament, and with the clerks of the peace for the several counties through which the line will pass ; he should consult the standing orders of both houses, or be supplied with such extracts as relate to his department. In his estimates there are unfortunately many difficulties ; and most people forget the distinction between a railway being completed and opened, and opened and completed. Besides this, let an engineer be ever so much inclined to make a full and clear exposition of the cost of a line of railway, he may plainly see that if he does so the line will never be made, although it would be a profitable speculation. We should recommend, nevertheless, that no other but a correct and fair estimate should in all cases be furnished, in order to compare it with the traffic. For this purpose, every known bridge and viaduct should be separately computed, and ample allowance made for occupation bridges ; the land, together with all the earthwork, tunnels, fencing, and permanent way should then be calculated, the secretary furnishing an estimate of the office expenses, printing, sta-

tionery, travelling expenses, law, advertising, conveyancing, and all other items of this kind. At least ten per cent. should be added to the engineering estimate for stations, and the machinery connected with them, and a full allowance for engines and carriages. When every thing that can be thought of is thus collected together, allow not less that twenty-five per cent. for contingencies ; and note that by a mean of nearly 100 railways, the whole number of bridges average $2\frac{1}{4}$ per mile.

In estimating for rock, as this is seldom found except in deep cuttings, it may generally be taken as earth-work, with the necessary slopes. For instance, in a cutting forty-five deep, with slopes two to one, and a base of thirty feet, the sectional area of the opening, and of course the cubic contents of any given length, is four times the area of the cut of the same length with vertical sides, and a price on a rock cutting thus taken out, may be put at four times as much as the earth cutting with slopes, without any increase of estimate. In shallow cuttings this does not hold good ; but the excess may safely be thrown on the contingencies, the amount not being great, and the occurrence seldom. In a thirty-feet cutting, the difference is only three times, which may be sufficient when the rock is not very hard, with the saving in land to assist the price ; but in a sixty-feet cutting, with slopes of two to one, the quantity is five times that of vertical cutting, and with the saving in the land occupied by the slopes, would make the rock cutting much the cheapest, unless of extraordinary hardness. It will take more time to cut through the rock, length for length, but would not if it could be entered at several places at once. Where land is extremely valuable, it will in many cases be cheapest in a cutting to support the sides with retaining walls, purchasing little more than the absolute width of the railway.

The width of the land required, will of course vary with the depth of the cuttings and length of the embankments,

together with the slopes necessary to be given; rock, for instance, stands generally vertical, chalk varies from $\frac{1}{6}$ to 1, to 1 to 1; gravel $1\frac{1}{2}$ to 1; the coal measures $1\frac{1}{2}$ to 1. The London clay has been made to stand at 1 to 1, and has slipped at 3 to 1, depending greatly upon the dryness of it when tipped into the embankment. Blue soapy shale has slipped at 4 to 1, for instance, on Bugbrook Downs, in Northamptonshire; and in every stratum there are great variations, much depending on the weather. Bad material in wet weather will often stand at no slope whatever. A double line will have ample width in fifteen yards, allowing two yards on each side for the drainage and fencing. The land required for this amounts to 5,455 acres per mile forward, and if 1·454545 is multiplied by the number of yards in perpendicular height, in any embankment or cutting, at slopes of 2 to 1, it will give the additional number of acres per mile forward, and by a geometrical average, the whole line may be very closely estimated in this way. For example, take a line of 112 miles in length, and 15 yards in breadth, for railway, ditching, and fencing, and averaging in height of embankments and depth of cutting 24 feet or 8 yards, then $5{\cdot}455 \times 112 = 610{\cdot}96$ acres for railway, ditching, and fencing, and $8 \times 1{\cdot}454545 \times 112 = 1303{\cdot}27$ acres, required for the slopes at 2 to 1, this giving a total of 1914 acres, and this mode of estimating may be considered to include the land required for stations and approaches to bridges.

It will be necessary to compute, in many cases, whether a viaduct will not be cheaper than an embankment. The method of doing this will be found in the article Viaduct. Where expense is a great object, timber may be made use of; beams of which, trussed with iron, have lately been introduced instead of arches, and to a great extent in some cases, for instance the Midland Counties railway. On the North Union railway, a timber viaduct is constructed of great height; several similar works are in course of execution in the north of England; and in some of the

Scotch railways the system of trussed beams of timber has been applied to very large spans. In many instances, a considerable reduction in the cost of bridges and viaducts may thus be made, especially where the crossings are very oblique, or where the additional height of arches would involve great expense in embanked approaches.

Should money be short and time so valuable as to make the expeditious opening of the line a subject of the first importance, great part of the excavations may be removed at night after the line is open, where they are not required for the embankments. This plan is not, however, to be recommended, and still less so making the embankments less than their full width at first; the additional patch of embankments hardly ever uniting equally with the part first made, but sliding off, and leaving the side of the embankment as smooth as glass.

Expense again may be saved where land is valuable, by iron colonnade viaducts, by which means towns may be entered much farther than is now possible to do without an enormous outlay. The cost of such a viaduct will in general not exceed two-thirds of a brick one of the same height and width; in fact, there are many ways in which expenses may be lowered, and the railway got into work in a speedy and safe manner at a moderate outlay; after which, if the project turns out a successful one, ornament may be attended to, to any extent which may be thought advisable.

In the same manner it should be calculated whether a tunnel or an open cutting will be the cheapest mode of getting through hills of importance. The method of doing this will be shewn in the article TUNNEL. Where rock is found at the bottom of the cutting, of course the sides may be nearly vertical, and the upper strata may have any required slope given to them. In such a case it will be advisable to have a tolerably wide bench where the change of slope takes place; this should be done in every case where

there is a variation in the slopes, and the drainage well attended to. By attention to these points, a greater saving will be made in the quantity of land required.

There are so many ways of computing earth work, all of them equally accurate, that the choice consists mainly in using the one which occupies the least time. Tables have also been published for taking out the cubic contents by inspection. The following formula, however, which we have arranged for this purpose, is so very quick in bringing out the results, that we have always given it the preference over any other method.

Let $a=$ the area in square yards.

$c=$ the content in cubic yards, per chain in length.

$w=$ the width in feet of the cuttings or embankments.

$h=$ the height in feet of the cuttings or embankments.

$m:1=$ the ratio of the base of the slopes to their altitude.

Then the rules applicable to every case will be

$$a=\frac{wh+mh^2}{9}$$

$$c=22a$$

And as 30 feet is a very general width, if we adapt our formula to that, we have with slopes of 1 to 1,

$$a=\frac{30h+h^2}{9}$$

$$c=22a$$

And with slopes $1\frac{1}{2}$ to 1,

$$a=\frac{20h+h^2}{6}$$

$$c=22a.$$

And with slopes 2 to 1,

$$a=\frac{30h+h^2}{9}$$

$$c=22a$$

And for any other widths and slopes the results will be brought out very quickly, by an adaptation of the general formula. By the particular ones given above, the tables on the

following pages were computed, giving the cubic contents per chain in length, at one view, for every foot in height, up to 50. In the column for the area, the decimals are given to three places of figures, but four places were used in calculating the cubical content. Where a dot is placed after the last figure in the column for the area, it denotes that the same figure goes on *in infinitum*. In using the column of cubic contents, increase the last decimal figure by 1 when it is above 5.

The columns of "half-widths," in the following tables, will enable the engineer to set out his work from the centre pegs as he proceeds. This is done at once, where the country is level, on the cross section; but in sidelong ground a correction will be required, to obtain which, after the half-width has been staked out, the level should be planted over the centre peg, and the height above and below the cross level taken at the points which mark the half-width. It is evident, that for each foot which these points may be above and below the level of the centre peg, one foot must be added to the half-width on the side which is above the centre, and subtracted from it on the side which is below, where the slopes are 1 to 1, and a corresponding alteration at all other slopes; or if we put

$h' =$ the height above the centre, or depth below it,
$m : 1 =$ the base to the perpendicular,
$c =$ the correction,
$c = \pm mh'$,

where c is $+$ on the high side, and $-$ on the low one. This will give a first approximation, and may be repeated if necessary, by levelling to the half-width thus corrected, and proceeding as before, and the cubic contents must receive a similar correction when necessary, our tables presuming the cross section to be on a level. The average height, however, can in almost every case be taken perfectly near enough for every practical purpose.

It is a great pity that the custom has not been generally

Slopes 1 to 1.				Slopes 1½ to 1.				Slopes 2 to 1.			
Height in feet.	Half width at top.	Area in square yards.	Contents in cubic yards, per chain forward.	Height in feet.	Half width at top.	Area in square yards.	Contents in cubic yards, per chain forward.	Height in feet	Half width at top.	Area in square yards.	Contents in cubic yards, per chain forward.
1	16	3·444.	75·777	1	16·5	3·500	77·000	1	17	3·555.	78·222
2	17	7·110	156·420	2	18	7·333.	161·333	2	19	7·555.	166·222
3	18	11·000	242·000	3	19·5	11·500	253·000	3	21	12·000	264·000
4	19	15·111.	332·444	4	21	16·000	352·000	4	23	16·888.	371·554
5	20	19·444.	427·777	5	22·5	20 833.	458·333	5	25	22·222.	488·888
6	21	24·000	528·000	6	24	26·000	572·000	6	27	28·000	616·000
7	22	28·777.	633·110	7	25·5	31·500	693·000	7	29	34·222.	752·888
8	23	33·777.	743·110	8	27	37·333.	821·333	8	31	40·888.	899·554
9	24	39·000	858·000	9	28·5	43·500	957·000	9	33	48·000	1056·000
10	25	44·444.	977·777	10	30	50·000	1100·000	10	35	55·555.	1222·222
11	26	50·111.	1102·444	11	31·5	56·833.	1250·333	11	37	63·555.	1398·222
12	27	56·000	1232·000	12	33	64·000	1408·000	12	39	72·000	1584·000
13	28	62·111.	1366·444	13	34·5	71·500	1573·000	13	41	80·888.	1779·554
14	29	68·444.	1505·777	14	36	79·333.	1745·333	14	43	90·222.	1984·888
15	30	75·000	1650·000	15	37·5	87·500	1925·000	15	45	100·000	2200·000
16	31	81·777.	1799·110	16	39	96·000	2112·000	16	47	110·222.	2424·888
17	32	88·777.	1953·110	17	40·5	104·833.	2306·333	17	49	120·888.	2659·554
18	33	96·000	2112·000	18	42	114·000	2508·000	18	51	132·000	2904·000
19	34	103·444.	2275·777	19	43·5	123·500	2717·000	19	53	143·555.	3158·222
20	35	111·111.	2444·444	20	45	133·333.	2933·333	20	55	155·555.	3422·222
21	36	119·000	2618·000	21	46·5	143·500	3157·000	21	57	168·000	3696·000
22	37	127·111.	2796·444	22	48	154·000	3388·000	22	59	180·888.	3979·554
23	38	135·444.	2979·777	23	49.5	164·833.	3626·333	23	61	194·222.	4272·888

Slopes 1 to 1.				Slopes 1½ to 1.				Slopes 2 to 1.			
24	39	144·000	3168·000	24	51	176·000	3872·000	24	63	208·000	4576·000
25	40	152·777.	3361·110	25	52·5	187·500	4125·000	25	65	222·222.	4888·888
26	41	161·777.	3599·110	26	54	199·333.	4385·333	26	67	236·888.	5211·554
27	42	171·000	3762·000	27	55·5	211·500	4653·000	27	69	252·000	5544·000
28	43	180·444.	3969·777	28	57	224·000	4928·000	28	71	267·555.	5886·222
29	44	190·111.	4182·444	29	58·5	236·833.	5210·333	29	73	283·555.	6238·222
30	45	200·000	4400·000	30	60	250·000	5500·000	30	75	300·000	6600.000
31	46	210·111.	4622·444	31	61·5	263·500	5797·000	31	77	316·888.	6971·554
32	47	220·444.	4849·777	32	63	277·333.	6101·333	32	79	334·222.	7352·888
33	48	231·000	5082·000	33	64·5	291·500	6413·000	33	81	352·000	7744·000
34	49	241·777.	5319·110	34	66	306·000	6732·000	34	83	370·222.	8144·888
35	50	252·777.	5561·110	35	67·5	320·833.	7058·333	35	85	388·888.	8555·554
36	51	264·000	5808·000	36	69	336·000	7392·000	36	87	408·000	8976·000
37	52	275·444.	6059·777	37	70·5	351·500	7733·000	37	89	427·555.	9406·222
38	53	287·111.	6316·444	38	72	367.333.	8081·333	38	91	447·555.	9846·222
39	54	299·000	6578·000	39	73·5	383·500	8437·000	39	93	468·000	10296·000
40	55	311·111.	6844·444	40	75	400·000	8800·000	40	95	488·888.	10755·554
41	56	323·444.	7115·777	41	76·5	416·833.	9170·333	41	97	510·222.	11224·888
42	57	336·000	7392·000	42	78	434·000	9548·000	42	99	532·222.	11704·000
43	58	348·777.	7673·110	43	79·5	431·500	9933·000	43	101	554·222.	12192·888
44	59	361 777.	7959·110	44	81	469·333.	10325·333	44	103	576·888.	12691·554
45	60	375·000	8250 000	45	82·5	487·500	10725·000	45	105	600·000	13200·000
46	61	388·444.	8545·777	46	84	506·000	11132·000	46	107	623·555.	13718·222
47	62	402·111.	8846·444	47	85·5	524·833.	11546·333	47	109	647·555.	14246·222
48	63	416·000	9152·000	48	87	544·000	11968·000	48	111	672·000	14784·000
49	64	430·111.	9462·444	49	88·5	563·500	12397·000	49	113	696·888.	15331·554
50	65	444·444.	9777·777	50	90	583·333.	12833·333	50	115	722·222.	15888·888

introduced of taking all the measures in yards and decimals, surveying staffs being marked to $\frac{1}{100}$ths of a yard. This would reduce the calculations considerably; and the reduction of any of them to feet, for plans and sections required in Parliament, or any other isolated purpose, would be infinitely less troublesome than using feet throughout, and having to divide by 9 or 27 for the area and cubic content.

The column of half-widths, when required for any other slopes or widths than those we have given, may be readily computed by the formula

$$x=\frac{w}{2}+mh,$$

where x is the half-width at the top, and w, m, and h as before.

The column of cubic contents, when required for any other width than 30 feet, may be readily found, by using a correction c' to the cubic contents at 30 feet, which correction is $+$ when the width is above 30 feet, and $-$ when below,

$$c'=\pm\frac{w'h66}{27}=w'h\ldots2{\cdot}4444 \text{ in cubic yards,}$$

where w' is the number of feet above or below 30, and h' is the height in feet. The correction is the same for all slopes, taking care to add or subtract it from the cubic contents for 30 feet at the given slope.

With reference to apportioning the work, so that the cuttings and embankments may be equal, regard must be had to the nature of the soil to be moved. For instance, in the London clay it will be found that any quantity of cutting will not make the same quantity of embankment by about ten per cent., whereas in common earth just the reverse takes place, and the cutting will make an embankment nearly ten per cent. greater.

There is a point, which, in the early stage of laying out a railway is too often lost sight of, that ought to be a subject of the deepest consideration; in fact, it is of vital importance to the whole interest of the line in question, and

no pains ought to be spared in most fully and rigidly investigating it ; and this is, to what extent cutting and embanking can be advantageously carried, that is to say, a line perfectly level, allowing for the curvature of the earth, from one end to the other, being the point of perfection, how near ought this to be approached, looking on the one hand at the first outlay, and on the other at the future gain, in the cost of locomotive power, and repairs of engines, carriages, &c.

We can calculate the cost, for instance, of making a line having no inclinations in any case greater than 1 in 300. With this line we should have a determinate outlay in locomotive power and repairs. The question to be considered then is simply this: If we make the line, instead of having no inclination, greater than 1 in 300, to have none greater than 1 in 500, or 1 in 1000, do we lay a foundation for a yearly saving, when the railway comes into work, sufficiently great to pay us for the consequent first cost of these reductions in the inclinations?

In order to enter properly into this question, experiments must be made for the purpose of determining the cost of locomotive power on the various inclinations, selecting some railway where different engines can be employed on inclines suitable for the case in hand, there being no data in existence, in this country at least, which can with certainty decide this point. The following table, by the engineer of the New York and Erie railroad, may help us a little :—

Ascent per mile, in feet.	Gross load in tons, 2080 lbs. each, *ex* tender.	Cost of motive power per ton per mile, in cwts.
Level.	75·25	3·50
10, or 1 in 528	49·53	4·20
20, or 1 in 264	37·35	4·90
30, or 1 in 176	27·24	5·95
40, or 1 in 132	20·22	7·28
50, or 1 in 105·6	17·04	8·19
60, or 1 in 88	13·92	9·66
70, or 1 in 75·4	11·31	11·41

This table, giving principally impracticable gradients, will only serve to shew us that the ratio of expense is an increasing one, the first differences being respectively 0·7 : 0·7 : 1·05 : 1·33 : 0·91 : 1·47 : 1·75.

If we admit, till we can obtain better data, that altering our gradients from 1 in 250 to 1 in 500, saves two-tenths of the expense of locomotive power, and that reducing it to a level instead of leaving it at 1 in 500, saves two more tenths, we can easily see what the effect of that would be.

The number of tons carried, as given in the table, is not decreased according to the law of gravity alone, but contains another element, most probably the result of experience on the road in question. Suppose then that on the road we are about to construct we may expect to work seven trains per day each way, with passengers, there being ten carriages in each train, averaging four tons each, and travelling at the rate of twenty miles an hour, and two trains each way with goods, in ten waggons per train, averaging goods and waggons five tons each, and going at the rate of ten miles an hour; also let the railway in question be one hundred miles in length; then at a cost of L.304 per day, the passengers being taken at eighteen in each carriage at $\frac{1}{4}$d. each per mile, and the goods at $\frac{1}{2}$d. per ton per mile, at which price it is known they can be carried, we may presume, that if, instead of having an inclination of 1 in 250, our road was level, we should decrease these expenses four-tenths, or bring them to about L.182 per day, or L.66,430 per annum. Thus, presuming the above to be correct, we should be saving money, if our road could be made level at an additional expense of one million.

Each particular railroad must of course form a separate case, but we are persuaded it will generally be found that a large outlay will be justified in approximating to a level as near as possible; and where the line is entirely so, the cuttings can always be cleared of water, by sloping the side draining down each way, from the centre till they arrive at

the nearest water course, where as usual they will deliver their contents. Our practical knowledge of this subject of reducing railways to a level is founded on such slight data, that a careful set of experiments in order to shew the way more fully into such a question is very much wanted; and we question whether hydraulic locks will not be found to save considerable expense in difficult situations, bringing the trains from one level to another, by which means railways may be made through tracts of country which would otherwise never pay for the necessary outlay.

The expense varies very much with the speed at which the carriages go. This would not be the case to any thing like the extent it is, if our road were level; for instance, since the speed on the Liverpool and Manchester railroad has been increased from twenty to thirty miles an hour, their expenses have risen from 1s. 8d. to 2s. 4d.

By a careful investigation into all these preliminary points, such a knowledge will be obtained of all the facts which are requisite to come to right conclusions, that the engineer may go to work with confidence, and the results will be such as must permanently benefit all parties concerned in the line. When they are decided on, and the act is obtained, the next stage is to prepare working drawings and specifications for the several contracts, and no contract should be let till the directors have fully approved of the specifications. These should be so divided if possible, that each contractor will be enabled to use all his excavations in his embankments; care being taken, however, that when the lead is very long, the expense of transporting the material from the cutting to the embankments does not exceed that of throwing it out to spoil, and forming the embankment from a side cutting. Long tunnels and viaducts should be separate jobs, and the contracts ought not, generally speaking, to extend above five miles, unless some proportionate advantage is gained in another way. The drawings for the bridges should as often as possible shew one side in a cutting, and the other in an em-

bankment, (see Plate CCCCXXVI. fig. 5), and they should, whenever it is practicable, have such arches as will enable the contractor to do with few centres, by removing them from one bridge to another, and as the number of bridges cannot yet be known, because they will depend on the nature of the agreements with the landowners, a full and complete schedule of prices for these and all other extra and additional works, should be made out, and form part of the contracts in every case. It is by some engineers thought a good plan to lay in the lower course of the arches dry, and grout them afterwards, as by this means the bricks have a more equable strain.

Turfing or soiling and sowing the slopes should form an item in the schedule of prices, or it is sure to be neglected; and if the contractor be bound to keep the permanent way in repair for a year after its completion, as is sometimes done, a large allowance must be made for this.

Those works which will take longest to execute ought of course to be the first let, so that the whole line may be completed as nearly as possible at the same time. It will be much better if no contract is let till the company are in possession of *all* the land belonging to that part of the line. Attention to this will most probably save the company many thousands; and if it be not done, exorbitant claims, which are sure to be advanced, will often have to be complied with, because the contractor is demanding the land, and very properly saying, that he cannot be bound to time, unless he be put in possession of his ground.

We strongly advise every company not to look at the lowest tender, but at the respectability, competency, and character of the parties who come forward to offer for the work. There are well-known persons who go about to offer for works of this kind, without the slightest intention of ever finishing them, who are in effect mere men of straw, borrowing perhaps a hundred pounds to make a beginning, and trusting to the chance of doing all the light and easy work,

which will pay them well, and then standing stock-still, till the company are glad to buy them out, after which they have to do all the heavy work themselves, at a proportionate cost, which is still farther increased by having to press the work in all directions, in order to make up as much as possible the time wasted by the contractor.

There is no way of preventing this but awarding the work to persons of established character, who will give in a fair estimate, and be content with a reasonable profit, and finish their work in such a way that they can look for future employment from the same parties; whereas there are many who in fact never make an estimate at all, but put in a round sum, taking no care but to be low enough, so that they may get the job. Many tenders of this kind have been put in at prices by which it was absolutely certain the parties must have lost several thousand pounds if they had completed their contracts.

The expected source of profit to these adventurers is the earth-work, and it would in a great measure be stopped if the system of average prices was abandoned, and the contractor paid for his cuttings according to the nature of the soil, and the length of the lead. If an average be at all taken, it should be a geometrical one.

Let us suppose, for instance, there is one million cubic yards to be moved, for which a price of one shilling per yard ought to be paid, and two hundred thousand cubic yards of rock, which ought to be charged at two shillings. Then the account would stand thus:—

1,000,000	cubic yards	at 1s.	L.50,000
200,000	ditto	at 2s.	20,000
		Total,	L.70,000

Now allowing that the averages, as far as the lead is concerned, were fairly taken, the above would be the proper price of the work, but if the final price agreed on is a single one, viz. the average of the above, we should have

1,200,000 cubic yards at 1s. 6d. L.75,000

Now, as the contractor would have to give in the total price of his contract, he would of course diminish that round sum by L.5000, the excess as shewn above, and throw off perhaps another L.5000, to be secure of getting the contract, and if he should happen to succeed, as most probably he will, from the lowness of his tender, he thus goes to work, getting all the short leads sub-let, for about 6d. to 8d. per cubic yard, and pockets the rest, and when he comes to the difficult parts he abandons his contract. We speak from a knowledge that such things have been done.

By far the safest and best system is to let the whole according to the lead. The contractor is thus paid fairly for his work, according to the quantity actually done, and the company are protected from frauds and loss of time. No parties who mean to do their work honestly, and complete their contract, would object to this.

There is a difference of opinion amongst those entitled to be the best judges, as to what sum of money should be retained from contractors at each payment, as a security for the performance of their work. On the one hand, such a retention should certainly be made, in order to give the company a proper hold on the contractor, and to ensure his fulfilling his contract; whilst on the other, if a large sum is retained, the contractor is very much crippled in his resources. So much depends on the character of the man, that it is difficult to give any fixed rule. If the work done is carefully examined by the respective assistant engineers, and not measured in till performed to their entire and perfect satisfaction, five per cent. steadily kept back, and on no account remitted till the final completion of the work, would in almost all cases be sufficient. Advances on large quantities of materials are advisable, and form a great accommodation to the contractor, always premising that the contract specifically states that the whole of the materials, when brought on the ground, become the property of the company.

The contract, when drawn up, should clearly define the nature of every species of work, the time in which it is to be done, and the penalty for non-performance. The general fault hitherto has been, that railway contracts have been drawn up too much in favour of the companies. This will defeat itself, as the Court of Chancery would set them aside. The contractor must have all reasonable access to the drawings, for the purpose of making copies, for the correctness of which, and the right setting out of the work, he must be answerable; and he should be bound to do a certain quantity of earth-work and brick-work in a series of definite periods. Whatever is in either the drawings or specification, should be considered as to be done, although it may not be in both; and it should be clearly defined how long and to what extent the work is to be kept in repair, and how far the contractor is liable for slips, and all other accidents.

He should be bound to fence in every part before he commences work, and to have the proper number of men and foremen on the ground, or the company should have a right to employ a sufficient quantity to make up the deficiency; not to enter on any adjoining lands without permission; to deposit spoil, if any, where ordered, within some specified distance from the railway; to make no bricks except for the railway, nor burn any lime without permission from the company; to open no roads without the engineer's leave, and then he must do it at his own expense; to give seven days' notice before commencing any excavation, embankment, tunnel, or bridge, or before striking any centres; to build bridges over the railway, if required, at a specified increase of price, with Roman cement and iron hoops, so as to require no centering, and where the height will allow it, to arrange the centering so, that if necessary the railway can be worked under it.

He should be bound to indemnify the company from all damage to the adjoining lands; to make no sub-contracts without permission; and to remove all unsound materials, or

the company may do so, and take down and replace all work improperly done, or the company may do it at his cost. All buildings and trees on the land should be the company's property, but all stone and minerals are to be specified, and the ownership stated. When stone fit for building is expected to be found in the excavation, a price should be given for works executed with it in the schedule of prices; and when it is likely to be fit for blocks, the contractor should be bound to excavate in the most advantageous manner, to procure as many as possible, under a penalty per block, on those not procured, and at a price per block for those delivered. All materials, when brought on the ground, should be the property of the company; the engineer should have power to alter and add to the works, on giving proper notice, at a fixed price; the contractor should do all work which may be implied or reasonably inferred, as well as what is expressed, and any disputes should be remitted to the principal engineer, whose decision should be final in all cases.

The mode of payment for the extra works should be defined; and these works should be entered in a book before they are begun, by the resident engineer, to which book the contractor should have all reasonable access, and be allowed to make copies. It is also usual, where there is much brick or stone-work, to advance the contractor a sum of money, when he has on the ground a large quantity of the materials.

The specification should state the extent and general stipulations; describe the temporary and permanent fencing, ditching, or quicking; the size and nature of the embankments and excavations, both in general and particular; the form and dimensions of the tunnels, if there are any; the descriptions and nature of all the materials that are to be used; the roads which are to be diverted should be stated; and a clear and definite description of all bridges either under or over the railway, and of all drains and culverts. The

manner of placing the blocks, sleepers, and ballast, and the mode of laying the rails, should also be clearly stated.

The contract works should comprise the temporary and permanent fencing; the formation of the embankments and excavations; raising or lowering land for dépôt-making; completing tunnels, viaducts, bridges, and their approaches; making drains and culverts, and laying and ballasting the permanent way; and finding all materials except the rails, chairs, pins, spikes, keys, blocks, sleepers, and treenails.

The extra works should comprise the erection of gates; building occupation bridges as soon as they are decided on; making the approaches to them, and metalling the roads; the paving of roads crossing the railway on a level; the building occupation culverts; laying and ballasting the permanent sidings; and the formation of tool recesses.

The plan should have the embankments shaded of a lighter colour than the excavations; but both should be distinctly shewn, so that the contractor may know which is the company's land, and where he may erect temporary houses, offices, and machinery, not prohibited by the act under which the company work. The section should clearly shew the heights and depths, on an enlarged scale, marking also the lengths at each chain, so that the contractor can readily compute the contents of the cuttings; the slopes of the various embankments and excavations being marked on each, and also the inclination of the railway, the levels for which the contractor in all cases must verify.

Each embankment should be uniformly carried forward at the proper height and width as nearly as possible, and the material tipped over the end should be trimmed to the required form at the time, and as the work proceeds; the material should be broken to pieces if requisite. The slopes should be trimmed into planes as the work advances, and covered with the turf taken from the surface of the ground, or with soil, if turf enough cannot be had,

observing that soil will not well lay on a less slope than $1\frac{3}{4}$ to 1.

Where the ground is of a mossy or yielding nature, every precaution should be made use of to secure the stability of the embankments. We have given a drawing of an approved method of doing this, (Plate CCCCXX. figs. 7 and 8); but as we consider that Chatmoss, over which Mr. George Stephenson carried an embankment for the Liverpool and Manchester railway, an instance of this kind of work, which it was most difficult to accomplish, we shall explain how that was done. The depth of the moss varied from ten to thirty-four feet, and its general character was such, that cattle could not walk on it; the subsoil was principally composed of clay and sand, and the railway had to be carried over it upon a level, and required cutting and embankment for upwards of four miles.

Where the mode of doing this required an embankment, the expense of which, in the ordinary method would have been enormous, as it must have been bottomed upon the subsoil of the moss, Mr. Stephenson contrived to use the moss itself in the following manner:—Drains about five yards apart were cut, and when the moss between them was perfectly dry, it was used to form the embankment, and so well did it succeed, that only about four times the quantity was required that would have been necessary on hard ground.

Where the road was on a level, drains were cut on each side of the intended line, by which, intersected with cross ones occasionally, the upper part of the moss became dry and tolerably firm; on this hurdles were placed, either in double or single layers, as the case required, four feet broad and nine feet long, covered with heath; on these was laid the ballast, and the method was fully successful. Longitudinal bearings, as well as cross sleepers, were used to support the rails where necessary, and the whole was thoroughly drained.

In the cutting, the whole had to be accomplished by drainage entirely. Longitudinal drains about two feet deep were cut on each side of the intended line of railway, and when by this means the upper portion of the moss had become dry, about twelve or fifteen inches in depth were then taken out, as in an ordinary case of excavation; the drains were then sunk deeper, and another portion taken out when dry, as before; and thus, by ultimately draining and excavating, the depth required for the railway was attained, which in some instances was nine feet, the embankments being as high as twelve feet. The only advantage in favour of these operations was, that the surface of the moss was higher than the surrounding country, which partially assisted the drainage; but when it is considered that, from the nature of the ground, an iron rod would sink by its own weight, it must be confessed that such an undertaking as carrying a railway along, under, and over such a material, would never have been contemplated by an ordinary mind. In a smaller moss which had also to be crossed, and which was about twenty feet deep, although an embankment of four feet high was required, the clay and gravel tipped amounted to as much as would form one twenty-four feet high in ordinary ground. The cost of Chatmoss embankment and cutting was L.27,720, and 670,000 cubic yards of raw moss formed 277,000 cubic yards of moss earth, the difference being occasioned by the squeezing out of the water, and consequent consolidation of the moss; yet the expenditure on this part of the line was under the average.

The contractor should make and maintain all the necessary drains, so as to prevent water from injuring the slopes and lodging in the excavations; and in case of sand or gravel occurring, he must protect the slopes from water by all necessary means.

Permanent drains, at a uniform depth below the rails, should be shewn on the drawings, to be made at the bottom of each slope, and others at the top, to cut off any water

which might flow from the land, and these must be made deep enough to carry off the water from any courses which may have been intersected by the excavation.

The contractor provides all rails, chairs, keys, pins, blocks, sleepers, waggons, barrows, or other materials or machinery necessary for the formation of the excavations and embankments, but may be allowed to use the rails laid down for the company, provided his waggons do not have more than three tons on one axle, if without springs, or four tons with springs.

The temporary fencing, which should be completed before the commencement of the works, and include the whole area where any work is to be carried on, may consist of split oak posts about 9 feet apart, and 3½ above the ground, morticed for 3 rails of oak or larch, with an intermediate post, the whole being substantially secured against cattle, sheep, or pigs, and made sufficient to protect the neighbouring land from trespass.

The permanent fencing may be oak posts and rails, brick walls or quicksets. If brick walls, they should be three feet above the rails, exclusive of the coping, which should be stone, the footings being carried at least one foot below the bottom of the ditch, holes being left in the wall for the water to drain through when necessary.

Quickset fencing should be placed within fifteen feet of the termination of the slopes, with a ditch six feet wide at the top, two feet at bottom, and two feet deep, which proportions may be varied according to the nature of the drainage, and the quantity of water to be expected. The outside of the ditch should be five feet from the boundary of the land occupied by the railway, the material from the ditch being used to form a mound, with the sides neatly faced with turf, the best of the soil from the ditch being put in the middle of the mound, on which should be planted good three-year-old quicks, two years transplanted.

Oak posts and rails should be placed to protect the quicksets.

The posts should be split oak, 7 feet long, and at least 5 inches by $3\frac{1}{2}$ in the sectional area, to be placed 9 feet apart, and $3\frac{1}{2}$ feet above the top of the quick mound, with the parts which go under ground thoroughly charred; the rails should be of split oak or larch, equal to $3\frac{1}{2}$ by $1\frac{1}{2}$ inches in sectional area, and ten feet long between the posts; there should be an oak or larch stay 5 feet long, and 3 by $1\frac{1}{2}$ inches in sectional area; the posts should be firmly fixed in the ground, and the ends of the rails, when they are driven into the posts, should be secured by nailing a piece of iron hoop to them, and round the head of the post.

The fencing should be as straight as the nature of the ground will admit; and the ditch should descend uniformly to the nearest existing main drain. The quicks should be cleaned twice a-year, and weeded with small three-pronged forks, and those which have not taken root should be pulled up and replaced by others. All broken posts and rails should be replaced at once, and the whole kept in good repair. At the bottom of the embankment a row of drain tiles should be laid through the quick mound at every hundred yards. Drain tiles are often very useful down the side of embankments, being let into the earth till their edges are flush, and standing on each other up to the top, in situations where much water runs down.

Embankments to form the approaches to bridges, are to be made from the surplus materials of the excavations. The surface should be made regular and even; then faggots or brushwood should be laid on, covered with ten inches of gravel, and where this has become hard, another coat of material should be laid on, eight inches in the middle, and three inches at the sides, the ruts being filled up from time to time, and the surface kept smooth and even. The roadway should be the same width as the bridge, and the embankment protected by posts and rails.

The laying of the permanent way and ballasting should

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be completed in such portions, and at such times, as will suit the execution of the other works; the engineer will direct whether blocks or sleepers are to be used, and when and where they are to be laid; but before any permanent way materials are delivered to the contractor, the engineer should certify that the surface of the embankments, and the bottoms of the excavations, are the proper height and depth, and of uniform width, level, and inclination, the whole completely drained of water, and in every respect fit for the permanent ballasting. (See Plate CCCCXX. fig. 6.)

The materials for ballasting should consist of broken stones or clean gravel free from clay, the broken stones not to be larger than cubes of two inches square. The ballasting should be uniformly spread over the top of the embankments, or the bottom of the excavations between the drains, and should be of an even thickness, ten inches where stone blocks are used, and eighteen inches with wooden sleepers, and well beaten into a firm and solid mass. Upon this ballasting the blocks and sleepers are to be laid, and the whole filled in.

When stone blocks are used, each block should be bedded into its place by alternately lifting it up and letting it fall, by means of a spring lever; theoretically, the block should fall with at least as great a weight as is likely to pass over it on the rail; this, however, is difficult to attain in practice. When wooden sleepers are used, the ballasting should be rammed down, and each sleeper beaten till bedded at the proper level throughout its whole length. If the contractor uses for his ballasting any suitable material that may be found in the excavations, he must make up the deficiency in the embankments by a side cutting at his own expense, indemnifying the company from the purchase of land for that purpose, if required.

Brick drains should be laid throughout the ballasting in the excavations. The stone blocks should be delivered to the contractor in the rough state, and he must drill them

for the treenails, which is best done by machinery, and level them to receive the chairs. A bed of felt, well soaked in tar, placed under the chair, will be found very serviceable in giving an equable seat to the chair on the block, particularly when the latter is composed of hard and compact stone ; with granite blocks, felt should always be used. The wood sleepers should be delivered as sawn out, the contractor making them level, and fit to receive the chairs ; the permanent way materials, when in the contractor's hand, must be considered in his charge, and he must be completely responsible for all loss and damage, giving a receipt to the store-keeper for each portion as he receives them.

When the engineer-in-chief and his assistants have been engaged, the reports, of which a list will be given, should be regularly made out, and a copy sent to the engineer-in-chief, and the manager or secretary. Agreements should be made with all of them, stating that, in case of dismissal, they should only be paid up to the date of such dismissal ; they should be allowed a proper number of overlookers, who should be paid weekly, and subject to discharge at the end of every week, like all other workmen.

The engineer in chief should have the power of suspending and discharging all persons under him. He will require a competent number of draughtsmen, who will have to make all the plans of land required, drawings for the contracts, and specifications for the various works ; occasionally assisting in measuring up and calculating that which is done, for the purpose of ascertaining the sums to be periodically paid, under the certificate of the engineer in chief.

But the most satisfactory way of paying for the work performed on the various contracts, would be for the company to appoint a measurer of their own, with the necessary assistants, to go always over the whole work prior to each payment. He should be accountable to the manager or secretary, and the committee alone, and report to them, without the least reference to the engineers at all. This would be a

complete check on the paper measurements so often relied on, and which are so uncertain, that no two persons can set down independently and measure a bridge on the plan, &c., without almost invariably differing several yards. We know a line of railway on which this was neglected to be done, although the necessity of it was pointed out by their principal officer at a very early stage, and the consequence has been the loss of thousands of pounds.

Able workmen and labourers will also be required to level and stake out the line and the land required; and to sink shafts in the proposed cuttings, where they may be wanted, for the purpose of ascertaining the strata, and other information necessary for drawing out correctly the specifications of the different contracts.

Whilst the engineer is employed in getting out the working drawings, &c., for the several contracts, the land-valuers will be using all their endeavours to get possession of the land in the order in which it is wanted. Public companies have been so grossly taken in on this head, and particularly railway companies, that it becomes imperative that something should be done at all hazards to protect their interests. We have ourselves seen the land for one of the principal railways just constructed, paid for at the enormous sum of L.5500 per mile, and another at upwards of L.330 an acre, or about L.5600 per mile, under all circumstances of fraud, delusion, and downright robbery, that can any how be conceived. No means were left untried, no artifices unresorted to, and the most barefaced falsehoods unblushingly set forth in aid of one vast system of plunder from beginning to end, with hardly any exception. They understand these things better in America. Juries there have actually awarded that landholders should compensate railway companies for bringing the line through their lands; whilst in England, it is notorious that the consent of men of great influence has frequently been obtained as a matter of policy, by agreeing to pay them amounts totally out of

proportion to the value of the land required; whilst others have purposely dissented, until they were bought off by a bribe. All these unnecessary extortions, as well as the enormous sums expended in order to obtain acts of incorporation, come, in most cases, ultimately out of the pockets of the public in the shape of heavier fares.

The first step in order to prevent this in other cases, will be to ascertain the fair value of the land, and of the requisite compensation, and whoever asks more than 25 per cent. above that value, hand him over to a jury that minute. If this course be in the beginning avowedly and unhesitatingly adopted, there is no doubt the interests of the company will at any rate be protected from those gross cases of pillage which have lately taken place.

In order to render this complete, the agent, or the land-valuer, should be engaged with on the following terms: Suppose 900 acres are required, and that if some greater precaution than has hitherto been taken be not put in force, then this land will average L.300 an acre, or the whole will cost L.270,000. Now, if the remuneration to the land-valuer be made upon a scale which increases, whilst the price of the land decreases, the amount may stand as follows:

Land-valuer's pay per cent.	When the price is, or above per acre.	Total land-valuer's pay.	Saving to the company.
$\frac{1}{4}$	L.300	L.675	nothing
$\frac{1}{2}$	275	$1237\frac{1}{2}$	22500
$\frac{3}{4}$	250	$1687\frac{1}{2}$	45000
.1	225	2025	67500
$1\frac{1}{4}$	200	2500	90000
2	175	3150	112500
$2\frac{3}{4}$	150	$3712\frac{1}{2}$	135000
4	125	4500	157500

The above per centage must only be paid in this way.

For example, if the land, when totalled, is found to be between L.200 and L.225 per acre, then $1\frac{1}{4}$ per cent. is paid on a supposititious price, namely, L.200 per acre; when it is between L.225 and L.250 per acre, 1 per cent. is paid, rating it at L.225 per acre, and so in all other cases.

The scale of remuneration will require adaptation to peculiar circumstances; in fact, if the principle above laid down be adhered to, the details are immaterial; all that is necessary is by a bonus of L.4000 or L.5000, exciting the land-valuer to the most rigid attention to economy, which, combined with a firm resistance to every attempt at extortion, will no doubt in most cases prevent the gross impositions which have been latterly put in practice. The short-sighted land-holders, by their outrageous opposition, may have here and there driven a railway into a bad curve, but, by causing so much discussion, they have mainly contributed to the rapid spread of the system.

From the earliest commencement of operations, the secretary or manager should, as occasions arise, be gradually getting out a series of memorandum books. This is absolutely necessary. At first, a "Memoranda of payments," and a "List of applications for situations," will be all that is necessary. The former should contain an entry of every check drawn on any account whatever; a sheet, containing a "List of payments," should be laid before the committee at their periodical meetings, and, if approved by them, entered in the minute-book at the end of the proceedings; the same is then entered in the "Memoranda of payments," giving the number of the check, the name, amount, what for, and the head under which it is to be placed in the company's books; this book is then sent to the accountant clerk, and from it he draws the checks and makes the necessary entries, or, which is still better, the checks may be drawn the day before the directors meet, and signed at once when the list is approved.

The list of applications should contain the name, age,

residence, trade, and general appearance of the candidates, also any recommendations or other remarks, and the nature of the situation he applies for. This forms a valuable resource, and enables the best men to be selected at all times when situations become vacant.

When the line is surveyed, a plan and section will be delivered to the secretary for the use of the directors; and the engineer will then begin to send, as fast as possible, separate plans of each land-owner's property, beginning with those first wanted. These plans should be entered by the secretary in a memorandum book, called "List of plans deposited," containing the county and the parish in which the land is situated, the name of the owner, and the quantity of land required; these, when the book is open, should form the left-hand page, about six entries being enough in a page, whilst on the right-hand should be entered the date when duplicates of the plans were sent to the solicitor and land-valuer, and dates when any letters were sent to them on the subject. The land-valuer should have the first copy, and the solicitor the second. The land-valuer then makes his bargain with the owner of the property, and sends his agreement, when concluded, to the secretary, to be laid before the directors for their approval; and when it has received their sanction it should be copied into a book, and the original sent to the solicitor, to enable him to make out the conveyance. It will save trouble if there are two books, the one to be called an "Agreement book," and the other a "Contract book," not that there is any difference between an agreement and a contract, but for this convenience: Perhaps two-thirds of the agreements entered into with the land-owners and occupiers will be so much alike, that a printed form can be drawn up, with blanks for name, quantities, parish, &c., which, being bound up in a book, saves a great deal of trouble, there being nothing to do but to enter the few written words in the agreements in this book. Others, again, will be so multifarious in their

clauses, that this cannot be done; these, therefore, have to be written out at length, and to distinguish the books, they may be called contracts.

The solicitor having received the agreement, will, if he finds it correct, and the title good, request a check for the money by letter to the secretary, and pay it to the land-owner, making out the conveyance forthwith. We strongly advise all directors of railways to insist on this latter point; for if the conveyance be not at once made out, and the transaction brought to a final conclusion, there will be no end to the trouble at a future period, and in a few months the whole will get into a state of inextricable confusion.

As the land is bought it should be entered in a book, called "Payments for land and compensation," which book should shew the name of the owner, the name of the occupier, the parish and county, the quantity of land taken for the railway, the quantity taken from any other cause, such as small pieces cut off, &c., the price per acre, the sum paid for the land, the sum paid for compensation, noting on what account, such as severance, damage, cutting off water, altering roads, and the like; the sum paid for buildings, noting their number and general character, and whether any are not required to be taken down for the railway; also what is the number and value of the timber bought, what land, buildings, and timber remain to be sold by the company, distinguishing those buildings which must come down, from those which remain up; the number of the check or checks through which the payments were made; the initials of the solicitor and land-valuer, if there are more than one, or, which is still better, a separate receipt-book, in which the person appointed to pay for the land, signs for each sum as he has it delivered to him, keeping a similar book himself, signed by the secretary, each receipt being numbered; and, lastly, a reference to the agreement or contract made for the purchase of the land, for the purpose of consulting it at all times in its proper book.

The land, timber, and buildings, not required for the railway, should be all entered in a book, called "List of disposable property;" this should have the parish, quantity of land or timber, number and description of buildings, late owner, why taken by the company, initials of land-valuer, by whom taken charge of, by whom sold, to whom sold, price of each description of property, to whom the money was paid, date of the company receiving the money, person who received it, and number of agreement by which the company get the land, and, lastly, the number of the agreement by which they sold it.

As, when the works begin, there will be constant claims for temporary damage, they should all be entered in a book called "Claims for temporary damage," and these should be periodically inquired into. The book should give parish, name of claimant, whether owner or occupier, reference to his letter by a number on it, reference to the person's letter who inquired into the claim, result of the inquiry.

An engineer's and solicitor's report book should also be kept; and in the latter, all letters requesting money to pay for land, should be copied at one end of the book.

Before beginning any contracts for the permanent way materials, a book of "Articles" in course of delivery, should be made, in which should be entered all contracts, stating the nature of the article, contractor's name and address, number contracted for, price, where to be delivered, time for completion of delivery, and penalty for non-performance of contract.

A store-keeper should be appointed, having assistants at each point of delivery, and proper places to deposit his stores under lock and key. These assistants should be qualified to judge the soundness and eligibility of the various articles which will be delivered to them. The storehouses should be, if possible, at the junction of every other contract for making the railway, and in every case, the parties supplying

the permanent way materials, should be bound to deliver them at the storehouses a stated quantity at each, in the proportion in which they will be required; the contractors on the line should be at the expense of transporting them from the storehouses to the places at which they will be used. The engineer having given in the quantities which will be required at each place, the whole should be put up to public competition by contract, in which the lowest bidder is to be considered as secondary to men of character and known competency to perform the work well.

The head store-keeper's books should contain for each article, every information as to quantity, quality, and price; when contracted for; when, where, and to whom delivered; by whom inspected; with the proper columns, shewing to whom supplied, and in what quantity, together with what remains in store. The deputy store-keepers need have to do with quantities only, and not with prices; their books should contain the same particulars as to the receipt and delivery, as the head store-keeper's, and should also shew what remains in store. Requisition and receipt books should be furnished, and when the contractor is ready to lay his way, he should write out a requisition note for the quantity he requires, making the same entry on the margin; the note being cut off, is sent to the resident engineer, who, if he approves of it, countersigns it, and it is then taken to the deputy store-keeper, who issues the required articles, and pastes the requisition note inside a blank book kept for that purpose; on the opposite side of which, he pastes the receipt note of the party who is supplied with the articles in question; the margin of the receipt book is also to have entered on it a summary of the whole.

A periodical inspection of these books should be made once a month by the store-keeper, who should see that they correspond with his own; and stock should be taken by him at each storehouse every quarter; for want of this system,

some railways have lost enormously; in fact, they have been totally unable to account for any one set of articles belonging to the permanent way.

In order that the directors may always be aware of how the works are proceeding, each assistant engineer should send in the following returns: A weekly return of all men in their employment, and the rates at which they are paid, and their duties; weekly return of earth got out of each excavation, shewing where it is tipped, and stating the remains; weekly return of cubic yards of brickwork done at each bridge, with the estimated quantity remaining to be done; weekly return of work done by locomotive, or fixed engine, shewing the expense in fuel, wages, and repairs; weekly return of all accidents, stating the men's age, and the number in their family; weekly return of men in the contractors' employ, distinguishing their trades, (the contractors should be bound under a penalty to furnish this to the engineer); quarterly return of permanent way laid; quarterly return of stock, and balance sheets for any work in the company's hands.

The engineer-in-chief should send in a monthly certificate of works done on each contract, on which certificates the contractors receive their pay; a monthly return of persons employed by him; a monthly return of the total sum paid on each contract, distinguishing the contract from the extra and additional works; monthly return of proposed alterations and additions to the works, which will increase the expense of the contract above L.10, stating the reasons for them. The engineer should be informed as soon as possible, what the directors decide in each case, and this return should be imperatively insisted on, and no unsanctioned alteration should be paid for.

The secretary must also furnish the engineer with a monthly return of all agreements entered into with the landowners, which relate to his department, such as bridges, crossings, culverts, drains, gates, fences, roads, watering places, &c., and any alterations which take place in these

should immediately be forwarded to him, copies being kept in each case. The secretary should enter all the above returns which come to him in a book for each, where they are to be kept in a tabulated form, and totalled up when requisite, so as to be able at all times to shew the directors the state of the works in every stage of their progress, and he will find nothing will compensate him for a want of method, order, and regularity, in keeping up these various accounts. In fact, as these are attended to, may the business of the office be considered well or ill conducted; it is from these returns that the directors, by proper attention, will be able at once to detect, if the requisite quantity of work is not done, and the attention of the engineer can be called to it immediately.

The accounts with the contractors should be kept as follows: There should be a constant check between the accounts, as kept in the usual manner of double entry, by the accountant clerk, and the check accounts, as kept by the secretary, and which are made up from the certificates of work and other documents. These latter should be drawn up, so as to exhibit on one opening of the book, the state of every contractor's balances. For this purpose, the secretary's book must be made out as follows: first, premising that he must have a temporary one till all the contracts are let, and then transfer the matter from the temporary one to a permanent one, in which each double page, when the book is laid open, should contain the whole of each contractor's account, at the date of the payments on the last certificates; and on the next payments, monthly or otherwise, these should be revised, the payments made, and work done, added on to the last totals, and the whole re-entered on a new double page, noting that if any advances are made to the contractor, on any thing but the usual monthly certificates of work, or if any other occurrence changes the balance between these periodical periods of re-entry; the proper corrections should be made in the last open page.

The book should contain the following columns, viz.

The name of the contract, or its number, or other designation.

The name of the contractor.

The length of the contract, and stating if it is a tunnel or viaduct.

The amount of the contract.

The contract works as certified.

The additions as certified.

The subtractions as certified.

The extra works as certified.

The advances and debits.

The total payments.

The reserved fund on the contract payments.

The reserved fund on the extra payments.

The balance on the contractor's account.

This will be found a most useful and important book, and should be carefully and rigidly kept up at each monthly payment. Quarterly statements by the accountant clerk, should be drawn out for each contractor, and compared minutely with the above book, and any discrepancy at once corrected.

There should be no such thing as advances of money on either work done or materials delivered, except in the regular way ; and if this rule is broken through, there will be no end to the error and confusion which will inevitably result ; but if, in an unavoidable case, there should be any advance made on a forthcoming certificate of work, it should be fully written down on the back of the certificate, with a complete history of the transaction, stating at whose recommendation it was done ; and these certificates, when done with, should be filed and put by as matters of standard reference.

When materials are sent in, an invoice should be, in all cases, delivered with them to the assistant store-keeper, who, in presence of the party delivering them, should state on the invoice, the quantity received, and the quantity re-

jected, giving the deliverer a counterpart of this corrected invoice as a back note. And after making the corrections, both as to quantity and price, he should forward the invoice to the store-keeper, who checks the whole, enters it in his books, and then corrects and signs the duplicate invoice he will receive from the secretary, and sends it back to be laid before the committee, who will order the payment. No advances on invoices should ever be made, but each separately paid up. This method should, in all cases, be rigidly adhered to, if ease and correctness be desired in opposition to error, negligence and confusion. By this method, the accountant clerk's books will be always entered up to the day, and the proper comparisons can be made with the engineering and store accounts, as kept by the secretary and store-keeper.

As we have found much misconception upon the part of accountant clerks in properly working out this system, even to the extent of journalising nothing, we may say with reference to their books, that in the case of an invoice, for example, on receiving it with an order to draw the check for the amount, they enter the amount in their cash book, and enter the invoice in their journal; then turning to their ledger, they enter "to cash" on the one side, and "by invoice" on the other, in each case making a reference to the proper book, in which the previous entries were made.

For a certificate of work the process is exactly the same; when the check is drawn, that is, entered into the cash book, and the whole of the certificate is entered in the journal, then the ledger would stand, "to cash," on the one side, and "by certificate" on the other, with the proper references, as before, to the cash book and journal.

It will frequently happen that the work certified as done in the monthly certificates, and the money paid, will differ considerably; for instance, deductions for damages done to the permanent way materials, by improperly using them, fines for not sending in returns, depreciation of the value

of locomotives, or other engines lent them ; and as all these things should appear in the ledger as well as the journal, we would recommend the debtor side of the ledger to be ruled as follows, the creditor side remaining in the same form as usual.

Folio in journal.	*John Thomson.*	Work done	Less retentions, 5 per cent.	Less debits	Dr.
		L. s. d.	*L. s. d.*	*L. s. d.*	*L. s. d.*
201		2000 9 6	100 0 5$_{4}$	201 2 3	...
	By certificate,	...	...	...	1699 6 9$\frac{1}{4}$
		340 10 0	17 0 6	32 3 0	...
208	By certificate,	...	...	...	291 6 6

All these columns are summed at the bottom of the folio, and the totals carried forward in the usual way ; and on the creditor side will appear, under the head of " to cash," the sums actually paid in cash, viz. L.1699, 6s. 9$\frac{1}{4}$d. and L.291, 6s. 6d. ; and in the proper folio in the journal, will appear all the particulars of the work done, and whether it is contract, extra, or additional work, and the particular sums retained on each, as also all the particulars of the debits. And in making out a balance sheet, the work done would form the one side, and the money paid plus the debits, the other side ; and the difference (being the retentions) would form the balance due to the contractor. This, in conjunction with the secretary's book, where the works and payments are classed, and entered into more minutely, would form a perfect check, a complete comparison, and a never-failing source of security from error ; and from each of these books, kept by separate clerks, having no communication with each other, the secretary and directors could, in a few minutes, have two balance sheets laid before them, arrived at by perfectly independent means. It is only by those who have seen how accounts have been kept on some of the existing railways, that the above system will be fully appreciated.

Another very essential book is one in which the contract works are abstracted into quantities and amounts. It should be about eighteen inches long, and eight high. The first

column should contain the number of the certificate, then the dates from and to, then the items, such as fencing, brick-work, excavations, tunnelling, stone-work, and all other known items, leaving a few blank columns for unusual things, each column should be ruled to shew the amount of work in every case, and the price paid; and at the right hand end of the page, the amount of the whole of the contract works under that date should be shewn, the amount of the extra works, and additional works, and the totals. The last column should give the retentions. If each double page carries three certificates, it will leave ample room. They should be summed up at the bottom, and carried forward to each fresh page, so as to shew the total amount.

According to the length of the works, the book should be divided so as to give sufficient leaves to each contract. A book about an inch thick in leaves, would in most cases do for ten contracts. A similar book should be kept for the extra, and a third for the additional works.

The directors should be furnished with a weekly return of the work done, and the money paid upon each contract. This will be done most conveniently by means of skeleton cards, filled up from the assistant engineer's weekly returns. They should shew the name or number of the contract, the total quantity of excavation in each, the quantity of excavation done, the quantity which ought to have been done, (this will vary each week according to what has been done the week before,) the excess or deficiency upon the whole quantity done, the time since the contract began, the period for completion, the amount of the contract, and the sum paid.

It will also be convenient to shew, on the same card, the ratio of the excavation done to the whole; the ratio between the time since the contract began, to the whole time for the completion of the works; and the ratio between the money paid, and the total price of the contract. The following is an example of these ratios as given monthly on the London and Birmingham railway:

Ratios for the Blisworth contract, London and Birmingham railway.

MONTHS.	1835. Ratio of the ex-cavation done to the whole.	1835. Ratio of the elapsed time to the whole.	1835. Ratio of the sums certified to the whole price.	1836. Ratio of the ex-cavation done to the whole.	1836. Ratio of the elapsed time to the whole.	1836. Ratio of the sums certified to the whole price.	1837. Ratio of the ex-cavation done to the whole.	1837. Ratio of the elapsed time to the whole.	1837. Ratio of the sums certified to the whole price.	1838. Ratio of the ex-cavation done to the whole.	1838. Ratio of the elapsed time to the whole.	1838. Ratio of the sums certified to the whole price.
January	...	...	...	·12	·30	·09	·43	·70	·39	·80	·82	1·31
February	...	...	...	·13	·33	·10	·43	·73	·39	·82	·85	1·34
March	...	...	...	·16	·37	·12	·43	·57	·39	·83	·81	1·38
April	...	...	...	·17	·40	·13	·45	·60	·66	·85	·84	1·40
May	...	...	...	·19	·43	·16	·49	·62	·69	·89	·86	1·48
June	...	...	...	·21	·47	·17	·55	·65	·74	·89	·90	1·57
July	...	...	...	·24	·50	·21	·60	·67	·86	·93	·94	1·66
August	...	...	...	·28	·53	·24	·65	·70	·97	·95	·97	1·74
September	·04	·17	·03	·31	·57	·27	·69	·72	1·05	·97	·99	1·85
October	·05	·20	·03	·36	·60	·32	·72	·75	1·15	·98	1·02	1·91
November	·07	·23	·05	·39	·63	·35	·79	·77	1·25	·99	1·05	1·99
December	·10	·27	·07	·43	·67	·39	·78	·80	1·27	...	...	...

By the above specimen it will be seen, that such cards as these, sent in with regularity to the directors, would enable them to be aware at once, of any negligence on the part of the contractor, as was evinced in this case; the neglect being apparent by the ratio of the work done, and that of the money paid, being both much less than the ratio of the time expended; till at the end of 1836, $\frac{67}{100}$ths of the time for completing the contract had elapsed, whilst only $\frac{43}{100}$ths of the earth-work has been done, and only $\frac{39}{100}$ths of the whole work. It was seen by this, that the contractor either could not, or would not, complete his work, and that the company must take it into their own hands. This took up three months, during which every thing stood still, except time; and in March 1837, that ratio would have been $\frac{77}{100}$ths if the time had not been extended. The increase in the money ratio from 39 to 66, was principally caused by the sum paid to the contractor to get him out. The time was again obliged to be extended in February 1838; and the contract, which was let for L.112,950, ultimately cost not far from L.250,000.

These cards also serve to check the amount of expenditure on each contract. When the ratio is found to be fast approaching to that of equality, and it is seen that the work is far from complete, the necessary inquiries ought to be instituted forthwith. But the best way of examining the rate of expenditure, and ascertaining whether it is likely to exceed the original amount, will be to make out a periodical estimate on the following principles.

Let us suppose the company's accounts made up every six months, under the following heads; viz. land, works, engineering, law and conveyancing, direction, office expenses, and sundries, which latter item will include advertising, printing, travelling expenses, and all other incidentals. From the total money expended since the first sixpence of outlay, subtract the sum expended on works, that is to say, on the contract works along the line. To the re-

mainder add the estimated amount of extra and additional works; the total sum for which all the contracts are let, and 25 per cent. for contingencies on the money yet to be paid; the sum to be paid for land *pro rata;* the expenses under the head of engineering, rating them according to their increase and decrease as the works proceed; the law and conveyancing yet to be paid for; the direction up to the probable period for opening the line; and the office expenses and sundries up to the same period. The engines and carriages must next be added, and then an allowance made for expenses on the works which may have arisen from any unforeseen or uncontrollable difficulties not contemplated in the contingent sum allowed under that head.

The only means of acquiring a knowledge of this latter allowance, will be by studying the monthly ratios as given on the cards, and sedulously comparing the rate of progress on each contract with the cost, and watching the amounts paid for extra and additional works, after the contracts have been in full progress a few months. This may be done with a considerable degree of accuracy. The cost in the other items must be taken upon a prospective view of what has been paid on them, together with what portion of them is done, combined with what portion there is to do. The rate will therefore be an increasing one, for instance, in the engineering expenses, till the works are nearly completed; then as the various contracts are finished, it will decrease. The office expenses may be considered as always on the increase; the land will increase in its rate per acre, from the numerous small compensations continually coming in; and the conveyancing will in general fall most heavy at the latter end. When all is summed up, allow at least ten per cent. contingencies on the money yet to be paid, except for works, and the total will form the estimated cost of the railway when complete. By the above method, the writer of this article detected the ultimate expense of a railway in which the original estimates were much more than doubled,

two years before any other persons connected with it would at all credit the possibility of such an event.

Cards shewing the earth-work, should also be made out as on the opposite page.

These cards should be made out in the same way as the above for each contract along the line; and any alterations in the respective quantities should be periodically introduced as corrections. Similar cards should be made out shewing the number of bridges in each contract, and the number of cubic yards of brick-work and stone-work in each; a return being then made of the work done to each, the respective quantities may be set off, and the ratio of the remainder to the whole quantity given.

A very useful mode of shewing how the whole works are proceeding, as it respects their time of completion, will be to draw up occasionally a table similar to the following, where the state of fourteen contracts are shewn, and the time which will be necessary to complete them on two suppositions. Column (*a*) gives the time to complete, supposing the excavation to proceed at the same rate which it has done during the last six months, or some definite period of time, including a fair average of weather; and column (*b*) gives the time required to finish, presuming the rate of expenditure to proceed as it has done since the works began.

Time required to complete the following Contracts

Jan. 1, 1837.	District 1.		District 2.	
Contract No.	Months. (*a*)	Months. (*b*)	Months. (*a*)	Months. (*b*)
1	1·06	14·5	26·6	31·3
2	1·10	12·1	9·0	24·4
3	1·18	10·2	19·2	4·4
4	1·44	16·3	22·3	13·4
5	1·17	12·8	44·3	34·3
6	·25	5·3	8·2	22·0
7	1·96	18·0	35·3	40·3

Coventry Contract.		Embankment. 1.	Embankment. 2.	Embankment. 3.	Embankment. 4.	Embankment. 5	Embankment. 6.	Spoil.	Surplus for ballast, approaches, shrinkages, &c.
Total Contents.		363,200	292,600	3,900	13,400	5,900	167,600	18,000	115,600
Excavation.	Cubic yards.								
1	148,500	148,500	...	...	...	...	...	...	...
2	222,300	214,700	...	...	...	...	...	...	10,600
3	253,400	...	253,400	...	...	...	...	...	...
4	111,900	...	39,200	3,900	13,400	...	...	...	55,400
5	9,700	...	...	...	...	3,000	...	...	16,700
6	9,700	...	...	...	...	2,900	6,800	...	...
7	193,700	...	...	...	...	...	160,900	...	32,900
Tunnel,	18,000	...	...	...	...	...	...	18,000	...
Total,	980,200	...	...	...	...	...	...	...	...

Where the time in column (a) is the shortest, as in contracts 6, divisions 1 and 2, and 2, division 2, it shews that the contractor, although very forward with his excavations, is very backward with his other work; and where column (b) is the smallest, as in contracts 4 and 5, district 2, it shews that whilst the other work is well forward the excavations are behind. Contract 3, district 2, is a tunnel, having a few thousand yards of excavation at the end. The state of this is very satisfactory; it will only take $4\frac{1}{2}$ months to complete it, judging by the money which has already been paid, hence the tunnelling must be nearly done, whilst, judging from the rate of excavation it will take nineteen months; the contractor has evidently been excavating only for his tunnelling, leaving the open ends till the last, when, by putting all his strength on them, he would most probably finish them in a few weeks.

When the delivery of the permanent way materials commences, duplicate invoices should be sent to the secretary in every instance, and be entered in a book on the left-hand page, and on the right-hand should be noted all that is done with them; such as the date, and by what conveyance they are sent to the store-keeper; whether they are correct or not after he has examined them, his alterations being all entered in the book; the date when they were sent to by him to the secretary; when paid; and to whom; with the number of the check, and any other remarks which may be thought necessary.

A book should be kept which should shew at one opening all the permanent way materials delivered, summed up in every page, and duly carried forward; and in case more than one person be delivering the same article, the list should be kept separate. At the head of each column should stand the whole quantity required, and the quantity contracted for.

When the works are in full operation, the principal duty of the directors and secretary will be to watch carefully the

progress of the different contractors, and by a timely exertion of their authority as often as it is necessary, keeping up a proper rate of advance whenever the weather will allow it; and if any of them should permanently persist in not doing his allotted quantity, notice should be given him that the company will set on men to make up the deficiency, which they must take care to reserve to themselves the power of doing by the terms of the contract.

There are several ways in which earth-work may be hastened, for instance, the use of locomotive and fixed engines to draw the earth along, both of which will be cheaper than horse power; and as no very rapid speed is required for this work, a cheap description of locomotive engine might be constructed, fully able to take a train of earth waggons at the rate of eight or ten miles an hour, and not costing more than L.700 or L.800, whereas a good passenger engine, made in the best manner, will cost L.1500. One large tube would be sufficient for all common purposes.

A common moveable steam-engine, working with a rope, will be cheaper than locomotive power, but not so convenient; if used, advantage should be taken in all cases of gravity. Loosening the ground with a plough will be very advantageous where the soil will permit it, such as clay, marl, and sometimes shale; and as the quantity of work which can be done is limited by the tip, this must be paid every attention to. The usual mode, by running sidings out from the main line in the form of a fan, so to have as many tipping places as possible, requires modifying. At present the common practice is to take up and relay the rails as the embankment proceeds, which consumes a great deal of time, and gives a corresponding portion of trouble, instead of which, if longitudinal bearers are framed for each tipping place, these can be at once lifted up all in a piece, and carried forward, and a rail put in behind them, in a very short space of time, and with one-fourth of the trouble which is found in the old way. When the embankment is not

high, these frames may be supported from below on a railway, and be moved forward any length that may be required. A horse should be kept for tipping above, and he may take in three waggons at a time. By making the above frames to propel forward, and having a door in the bottom of the waggons, the quantity tipped may be very considerably increased.

Whenever the lead gets above $1\frac{1}{2}$ miles, and there is much to do, a locomotive engine should be employed, the expense of which, including fuel, wages, repairs, interest on capital, and provision for a renewal every five years, will not exceed L.4 per day; the engine will take 24 waggons per trip, at 10 miles an hour, whilst a horse taking three waggons will only go 15 or 16 miles per day. That a great saving will ensue is clear, and may be thus shewn. Let the lead be two miles, and the contractor required to tip 1200 cubic yards per day; this would require 150 two-yard waggons, besides spare ones, and as a horse with three waggons would make four trips per day, or 24 yards per day, $\frac{1200}{24}=50$ horses, besides spare ones and tipping horses. Now these waggons are to be constantly travelling, and to keep these going, there must be 24 always filling, and 24 tipping. This, with the requisite number of spare ones, will in the whole require about 220 waggons; whereas with the engine, 24 travelling, 24 filling, 24 tipping, and 24 spare, total 96, is all that is required, say 100. Here then is a saving of 120 waggons at L.20 each, or L.2400, which is considerably more than the cost of the engine, besides the 50 horses, which, with their harness, cannot be taken at less than L.25 each, or L.1250.

Again, take 50 horses' keep at 3s. per day, is L.7, 10s.; 50 boys at 1s. 6d., or 25 men going one to two trains, at 3s. is L.3, 15s., total L.11, 5s. per day, whereas the engine will not cost more than L.4. Under very unfavourable circumstances, a mean of 15,000 trips gave for a distance of 1969 yards, 15 waggons per train, carrying 25 cubic

yards, with a consumption of coal of 245 lbs., costing 2s. 4d., wages, 11¼d., repairs and sundries, 6½d., total, 3s. 9¾d. per trip.

The old way of working at the face of an excavation, and bringing it out by lifts, is now known to be more tedious, and consequently unprofitable, than running a gullet through at once, in which as many waggons as the contractor likes can be put in and filled, both by throwing in the earth from above, or having a stage over the waggons to run barrows on. To get the greatest quantity of earth, besides ploughing it, which plough may be often worked by a steam-engine, the method called "falling" may be resorted to, that is, digging underneath and then splitting it on the top with wedges, and with the help of long iron levers, bringing down a lump containing several cubic yards at once.

The contractor will find it best to provide waggons, engines, and rails, and to sublet his labour to small gangs of about a dozen men each, and a ganger. The best sort of rails for a contractor's use is the T rail, inverted so that the lower flange nails down on the sleeper, and requires no chair. 30 lbs. per yard will be enough, but from 40 to 50 lbs. is better, as these will will do for any thing, and 30 lbs. would be too light for clayey soils.

In any case where time is an object, the tip end of the embankment ought to be made much wider and steeper than it is intended, so as to get in more roads at the tip; and as the work proceeds, this extra width is pared off and thrown down below to increase the slope, which should be left a little too narrow at the bottom on purpose

There is another mode of increasing the tip, by which the time of forming a large embankment may be reduced one-half. This method is to form the embankment at twice in the following manner: Carry out the earth to the required width, say 20 feet high, and then come on and complete this with a second set of tipping places, say for 30

feet more in height; the waggons must run from the 50 feet level down to the 20 feet by means of inclined planes on both sides of the upper embankment, and from the width of the lower one, a great many roads may be put in at the tip; the upper part of the embankment is brought on in the usual way, and by this means the quantity tipped may be doubled.

Under favourable circumstances, a contractor ought to move 1000 cubic yards of earth per day at each tip, and this by the above process may be doubled, in fact the limit is the tipping, for, by running a gullet into the hill, getters and fillers may be placed as thick as will leave them room to work, the quantity of which depends greatly on the weather, the average number of working days being from 200 to 230, in which may be got, by having night shifts in summer, and 3, 6, and 9 hours' shifts in spring and autumn, about 3000 working hours. Under many peculiar circumstances, it will be very advantageous to lay in a line of rails, and place huts on it for the workmen on wheels; so that their place of abode always follows up, and is close to their work, in fact, a moveable village. Much, of course, also depends on the nature of the soil as to the work which will be done in this time; generally a filler will put into a waggon from 15 cubic yards per day in stiff clay, to 25 cubic yards per day in loose sand, and by falling the earth as before described, 1 getter will keep 3 fillers going, so that to keep up 1000 cubic yards per day, will take from 60 to 90 men, according to the nature of the ground.

Where there is much rock the natural stratification of it should be closely examined and attended to in the blasting of it, as a horizontal blast would in many cases bring down ten times as much as a vertical one, and the force of the powder will be increased by mixing saw-dust with it. The strength and disposal of the blasts must entirely depend on the nature of the rock, and also in some measure, on whether it can be used in the bridges, or other erections along the line.

The contractor will find it his interest to look out sharp for clay, and either to make his own bricks, or let his clay to a respectable brickmaker to make them for him, unless he happens to be very favourably situated as to carriage; he should also do all his waggon repairs, erecting temporary carpenters' and smiths' shops in some position adjacent to his heaviest work, but being careful they are so situated that they can be let or sold at the termination of his contract; he should always work towards his greatest job, and of course so apportion his men as to bring in the whole at one time at the end.

It may sometimes happen that, from unavoidable causes, a contractor will find it impossible to continue his work, and occasionally this will be done intentionally. To guard against the last has been already adverted to, but to guard against the first is morally impossible; for there are so many cases in which a man, with the very best intentions, is yet borne down by the uncontrollable force of circumstances, that no human foresight can by any possibility prevent an unfavourable result. As a general rule, it will be best for the directors, in every prudent way, to assist and encourage a contractor, and by every means in their power to enable him to complete his work, provided it be seen that he really is desirous to get on. If prices have risen against him, or if he has made a miscalculation, it will be most decidedly the best thing for the company to increase the amount, to remit his retained money, or by any means to get him to finish his contract. If this be not done, the consequences will be very uncomfortable. His inability will have first become manifest by his employing too few workmen. If the checks which we have explained put in force, this is seen at once. He is served with a legal notice, that, under the contract, the company will employ men if he does not, and charge their expenses against him. This will probably induce him to come forward and state what his difficulties are; then if the company do not assist him, he will tell them he must

give up his contract; he is, perhaps, a man of no capital, and his sureties are the same, so that the company have no resource but to take the work into their own hands. In the meantime, the work having fallen in arrear, there comes the tedious admeasurement of what has yet to be done, and two or three weeks' squabbling between his lawyer and the company's, as to the terms on which he is to give up the works, and perhaps references to umpires, each taking a week; then the company have to order waggons, engines, and tools of all kinds, and to find foremen, overseers, sub-contractors, and workmen, all at a vast expense, it being the fate of almost every public company to be charged higher than individuals. Whilst all this is going on, the work is so much delayed that the line cannot be opened at the time which was intended, the proprietors losing the whole proceeds. Then come the enormous expenses which are requisite to redeem the time as much as possible. Land has to be bought to make side-cuttings in order to form the embankments, and, in another place, to deposit the earth from the excavation, which is now to a great extent thrown into spoil; horse-runs are established at as many places as possible, to bring up the earth in barrows, and all this in addition to the regular work at the gullet and the tip; and when these things are taken into consideration, it will at once be seen, that the company ought never to agree to finish the work themselves, but as a dernier resort. There are on one of the railways in England, six contracts which were let for L.600,000, and which the company have had to take into their own hands at an expense of L.1,200,000. In one instance, the cost of the contract was more than trebled, so that any means should be resorted to in order to assist the contractor through his job; and we again repeat, that it is decidedly bad policy to take the lowest tender in letting the contracts. A man of character alone should be selected, and ought to receive very encouragement in the execution of his work.

All these chances of increased expenditure show how ne-

cessary it is to make ample allowances in the original estimate; we should say, that, after every thing is put down on the most ample scale, there should be an addition of at least 25 per cent. for contingencies, and if the traffic estimate will not bear this, means must be found of reducing the expenditure in other ways. A great deal may be done under this head in economising brick-work in bridges, by making arched openings in their piers, by having three arched bridges where they are large, by using as little stone-work as possible, and in rock cuttings by throwing across an arch from rock to rock. In stations a great deal may be done, as these may cost much or little almost at pleasure. The company will gain also by making their own trucks, horse-boxes, waggons, and second-class carriages, and if, with these retrenchments and a proper attention to the gradients, the estimate cannot be brought to the requisite amount, the whole had better be honestly given up.

On the other hand, however, it is almost next to an impossibility to compute the increase on the existing traffic, which will inevitably take place on the opening of a railway. Such an undertaking can hardly with fairness be said to increase the traffic; it positively creates it. Classes of persons begin to travel who never before thought of such a thing, trade is soon conducted in a totally different manner, all the relations of life begin to flow in a new channel, and we are certain that the most sanguine mind cannot foresee the extent to which railways will ultimately lead.

When the contracts along the line are fairly at work, one of the first knotty points which the directors will have to decide on, is, the width of the rails, their shape, the length of their bearing, and the form of their chair. The width between the rails has only lately become a subject of dispute; nearly all the railways prior to the Great Western, having been laid down 4 feet 8½ inches apart. Mr. Brunel has extended it to seven feet; the Irish railway commission recommend six feet two inches; several of the Scottish rail-

ways are laid down at five feet six inches; in fact, the variations run from four and a-half to seven feet.

The question of the stability of the carriages on the railway may be left out of consideration in looking at this matter, because the machinery will always require sufficient space between the wheels to insure this. Now, as four feet eight inches and-a-half are found to be enough for the good performance of an engine, which, with five and a-half feet wheels, will go on a level upwards of 60 miles an hour; as with five-feet wheels, Marshal Soult, on his visit to Liverpool just after the Queen's coronation, was taken over $10\frac{3}{4}$ miles of favourable ground on the Grand Junction Railway within 10 minutes; and as an engine has gone 60 miles an hour on the London and Birmingham Railway up an inclined plane, is it wise or prudent to make any change at all, and will any additional speed, which may be gained by increasing the width of the rails and the diameter of the wheels, compensate for the greater expense and the outlay which will constantly be required to keep the road in order on account of the increased weight? This will receive light from the experiments on the Great Western, but will not be fully decided until it be tried on the Irish or some other railways, as Mr. Brunel's rails are altogether different from most others in use. The plan recommended by the Irish railway commissioners, of putting the rails farther apart but not widening the carriages, merely making the wheels run outside the bodies, is a good one in some respects; but it would add to the expense of the works considerably, and the result would be exceedingly questionable.

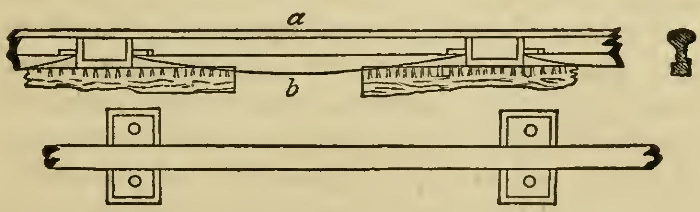
It must not be forgotten, that, where a different width from that in common use is adopted, the railway on which it is used becomes isolated. None but its own carriages can travel on it, and they can travel on no other line. This alone will, in most cases, be a serious objection. For our own parts we should say, let well alone; wait for more experience; we are yet infants amongst railways, and we ought not to inno-

vate on that which has been proved to do well, until we become giants. The majority of opinions, however, are beginning to lean towards some increase in the width, although there is every diversity in the quantity which practical men think necessary. Certainly the machinery under the boiler is compressed into its minimum space, and more room for it would be a great advantage, if it does not induce an incommensurate loss in other ways.

With respect to the form of the rail, it can be proved that a fish belly has greater strength, weight for weight, than any other. A 60lb. fish belly at three-feet bearings, rolled with a lower web, would be the best form of all; and this has been effected, as the original Liverpool and Manchester rails had partially this shape. The question, however, must be looked at in conjunction with the length between the supports. We have given below those forms most approved of in practice, and have added that in use on the Great Western Railway, which is however light, and does not stand well, three feet having been the original distance of the bearings.

Fig. 3 is the old Liverpool and Manchester rail, laid down at three-feet bearings; weight thirty-three lbs. per yard, with square joints. This rail was rolled with a lateral swell at the

Fig. 3.

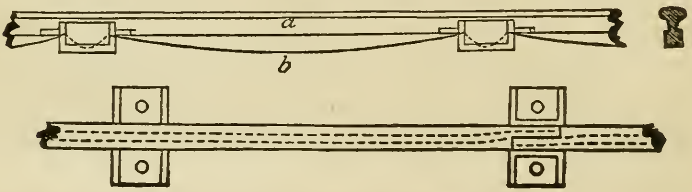


bottom, which on one side was continued the whole length, but on the other did not quite reach the chair. One side of the chair was cast with a cavity, into which the lateral swell fitted, and the opposite side had a nearly similar opening, in which was driven an iron key, shaped like a wedge,

which, entering in a longitudinal direction, not only forced the swell into the cavity which was formed to receive it, but by this means, at the same time, kept the rail down in the chair.

Fig. 4. Losh's patent rail, in which he sought to gain a still more powerful mode of keeping the rail down in the chair, by having his key tapered vertically as well as longitudinally, so as to act as a wedge downwards, as well as in the direction of its length; whilst, at the same time, the necessary expansion and contraction is allowed to take place. A key on each side has also been used with this form of rail, still, however, the keys were always found to work loose. Losh had also a projection rolled on the bottom of his rail;

Fig. 4.

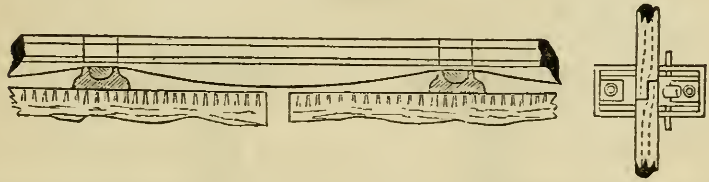


at the part which lies in the chair, where a corresponding cavity was cast to receive it, so that the effect of expansion or contraction would have a tendency to raise the rail in the chair, and thus wedge it tighter. The upper part of the notch for receiving the key in the chair was also formed with a slight curve, to allow of a small motion in the block, and the rails were made with a half-lap joint, formed not by cutting the middle rib of the rail, but by setting it back, so as to preserve its whole strength. They were laid down at three feet bearings, and weighed forty-four lbs. per yard, but of course were not restricted to that, or to any other weight.

Fig. 5. The London and Birmingham fifty pound fish-bellied rail. This was laid down at three-feet bearings, and the half-lap joint formed by setting back the middle rib instead of cutting it, in the same way as Losh's rail. It was keyed down by a pin going through the side of the chair in a di-

rection sloping downwards. The end of this pin went into a notch in the side of the rail, at its lower parts; the pin was forced tightly in by an iron key acting through the chair,

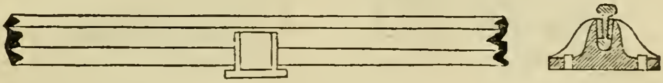
Fig. 5.



and also through a hole in the pin, by which it was driven both in and downwards; and the end of the key being split, was then opened, to prevent it being shaken loose. Mr. Stephenson has a patent for this chair. The rails did not rest on the bottom of the chair, but on a loose piece of iron, the lower part of which was the segment of a circle, and the upper part flat, and of the same width as the middle rib of the rail; and this worked in a circular cavity in the chair, so as to allow a motion when deflection took place in the rail. These rails had no bottom webs.

Fig. 6 is the St. Helen's and Runcorn rail, with a bottom web, having a semicircular base. These rails are forty-two lbs. per yard, and were laid down at three-feet bearings. A

Fig. 6.

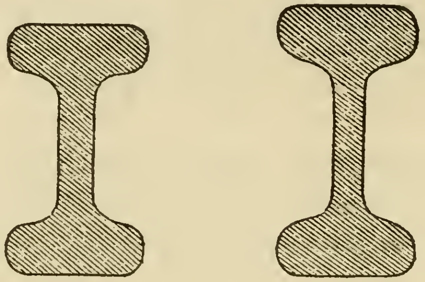


wedge on both sides is used, which acts downwards as well as sideways, from the opening in the chair to receive it being narrower at the top than at the bottom.

Fig. 7 shews the parallel rails laid down on the Grand Junction, and London and Birmingham railways. The left hand one is sixty-four lbs. per yard on the London and Birmingham, and sixty-two lbs. per yard on the Grand Junction. The right hand one is the London and Birmingham seventy-five pound rail. Rails of this kind are laid on seventy-five miles of that railway, and were intended to be at five feet

bearings, but proved a complete failure at that distance, which had to be reduced to three feet nine inches. The left hand one was intended to be at four feet bearings. These rails

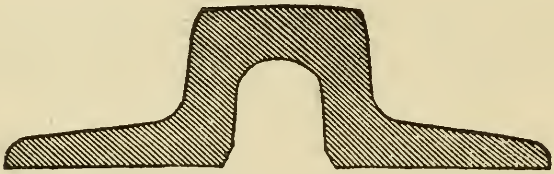
Fig. 7.



were both laid down contrary to the opinion of the engineer, Mr. Stephenson, and have entailed a vast expense on that company. They have wooden wedges.

Fig. 8 is the Great Western rail, laid on longitudinal timbers, and forty-four lbs. per yard. Felt is laid between the

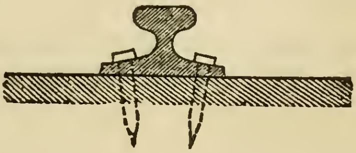
Fig. 8.



rail and the timber, and the former is fastened down with screws. It has been found deficient in strength for the heavy engines used upon that railway.

Fig. 9 has been frequently adopted on railways formed with longitudinal bearings. It is spiked down to the timbers, and requires no chair. The weights have varied from thirty-five to sixty lbs. per yard. Sometimes the spikes have not

Fig. 9.



gone through holes in the rail as in the figure, but have been driven in just outside each edge of the rail; in which case they are made with large heads, which come down and clip the rail firmly to the timbers.

The London and Birmingham Railway Company, after a long discussion, decided to try four and five feet with a parallel form instead of a fish-belly, which, requiring one-third more height in the chair, had, in addition to other disadvantages, that of being more liable to wring the chair from the block, which is found in practice to take place directly as the height of the chair. The block is also more loosened in the ground by a high chair, and the continual repairs arising from this loosening, amount to one-half the wages expended in repairing the way in general; hence every means of diminishing such a heavy item, which can possibly be devised, should be put in practice. As usual, where all was theory, there were considerable diversities of opinion. Those who wish to enter more at large on this subject, may consult Professor Barlow in favour of lengthening the bearings, and Lieutenant Lecount against it. As the matter has had a fair trial, it is only necessary here to state the results.

On the Primrose Hill contract, which was laid with four-feet bearings, it was found much more troublesome to keep the permanent way in order, than with bearings of three feet. With the four-feet bearings, it was found, that, in a very short time, the rails were put out of gauge, the width continually increasing, until it became absolutely necessary to readjust the whole. This was observed in a very marked manner with a part of the line near Kilburn, which had been recently laid down.

On the Harrow contract, from the crossing of the Harrow road to No. 12 cutting, the permanent road was used for conveying away the material from a side cutting. The traffic was of course considerable, but not by any means such as to account for the absolute difficulty which the contractors had in keeping the railway in guage. They were obliged to

put sleepers at the joints in addition to the regular number of blocks, which of course kept the rails in guage at those points ; but notwithstanding this, the intermediate blocks moved outwards. When the engineer's attention was first called to this position of the permanent way, he was inclined to think that something might be attributed to the blocks being placed anglewise ; but after giving this part of the subject his careful consideration, he felt satisfied that the position of the blocks was at least as firm as the square position ; and he felt confirmed in this opinion, by the fact, that, in another portion of the line near Kensal Green, where the road was laid in the ordinary manner with blocks three feet apart, and placed anglewise, and where locomotive engines had been constantly running for eighteen months, there was not found any greater tendency to a motion outwards, than when they were laid square to the direction of the rail, in the old manner. If, therefore, the diagonal position of the blocks had been defective, this was the place to try it ; for the quantity of material conveyed over this part of the permanent road in waggons without springs, and with heavy locomotive engines, was very great indeed, and under circumstances well calculated to detect any marked difference in the construction.

On the Berkhampstead contract, where five-feet bearings were in use, and where a locomotive engine was at work, the contractors made heavy complaints of the greater difficulty they had experienced in keeping the rails in gauge than there was with the shorter bearings. In fact, in the eighteen months prior to June 1837, the three-feet rails in some parts of the line, had more work than they now have, where the line is open ; yet they stood it well, whilst the five feet have been so put out of gauge by one day's work, that the waggons had to be stopped till one and two additional sleepers for each five feet could be laid down, and even then they were but indifferent ; and similar complaints having come in from other quarters, together with the fact that the

five-feet bearings on the Liverpool and Manchester railway were found to cost double the sum for keeping the way in repair that was required with three feet nine-inches bearings, the whole question had to be opened again, and the directors resolved to shorten the bearings from five feet to three feet nine inches.

This lateral deflection is of most serious importance, when we recollect that the rails being out of guage will throw the trains off the line. The lateral blows which an engine may give are such, that several chairs in succession have been broken or knocked off the blocks and sleepers; and the absolute weight passing over any one rail may be fairly taken as three times the nominal weight, for the effect from lurching has been experimentally found with engines having three tons' weight on each of the driving wheels to increase that weight to seven tons; besides which, we know that four-wheeled engines, for instance, will, in practice, be frequently running on three wheels, no railroad being a perfect plane; and when these three points are in the act of shifting, the engine during that time is only supported on two wheels.

The flexure produced by this weight perpendicularly has also this bad effect, that the engine and train are constantly ascending an inclined plane in practice, although the railway is considered as level, and of course where the railway has an inclination, that inclination will be proportionally increased. This was first pointed out by Professor Barlow, and is an important fact; for on the short planes between each block or sleeper caused by the deflection of the rail, the gain in descent is so insignificant, that it may be entirely neglected; consequently the engines and carriages are constantly going up an inclined plane between each support of the rails equivalent to the central deflection divided by twice the distance between the supports. This is, from calculation, ascertained to be as follows, viz.:—

Bearing distance.		Deflection.	Equivalent Planes.	Increased Power required per ton.
Ft.	In.	Inches.		
3	0	·024	1 in 3000	·75 lb.
3	9	·037	1 in 2432	·92 lb.
4	0	·041	1 in 2341	·95 lb.
5	0	·064	1 in 1875	1·20 lb.
6	0	·082	1 in 1756	1·30 lb.

Although the deflection of rails will generally be different from the above, and the increase of power required to surmount the consequent planes will also require considerable modification to suit the action of locomotive engines, which depend upon so many other circumstances besides the action of gravity; yet the fact remains the same, namely, that with deflection there is a consequent loss, and the subject deserves much more consideration than it has received, especially as we know that fish-bellied rails do not fail in the middle, but about eight inches from the supports. A rail ought not to act as a spring; but as this to a certain extent must be the case, it should be made to do so as little as possible. A spring should only be used to get over an obstacle where one must be met, but if the rail acts as a spring it creates an obstacle where none existed before. We must also remember that when deflection becomes permanent, fracture begins, as we break a thing we are not strong enough to pull asunder, by bending it backwards and forwards. In fact, the experiments on deflection have hitherto been such that they have merely served to unsettle all opinion, and to place one set of deductions in opposition to another. The mode of estimating this element by two wheels on an axle, loaded at their peripheries, and oscillated on the rails, is one which well deserves attention. In all cases, the firmer the rail is fixed to the chair, as respects rising in it, the less will be the deflection. Of course it must always have a motion in the direction of its length to allow for expansion

and contraction, the force of which will vary in good or tolerable iron from nine to six tons per square inch of section. The expansion of a fifteen-feet rail may be taken at ·00126 inches for each degree of Fahrenheit, and as it will not be safe to take less than 90° for the range of our climate, this gives ·1134 inches for the total, or ·0567 at each end of such a rail.

In order to understand the action which takes place in the case of a deflected rail when a heavy weight passes over it, we must know the effect of gravity at the velocities used on railways. For this purpose, if we take three, four, and five-feet bearings as those which seem at present likely to be the limits, the following table will give us the time occupied in going over half the rail in each case; and from this we shall be able to ascertain the effect of gravity during that time.

Velocity in miles per hour.	Velocity in yards per minute.	Velocity in inches per second.	Parts of a second in which 18 inches are passed over.	Parts of a second in which 24 inches are passed over.	Parts of a second in which 30 inches are passed over.
10	293·33	176	$\frac{1}{9\cdot8}$	$\frac{1}{7\cdot33}$	$\frac{1}{5\cdot86}$
20	586·66	352	$\frac{1}{19\cdot6}$	$\frac{1}{14\cdot7}$	$\frac{1}{11\cdot73}$
30	879·99	528	$\frac{1}{29\cdot3}$	$\frac{1}{22}$	$\frac{1}{17\cdot6}$
40	1173·32	704	$\frac{1}{39\cdot1}$	$\frac{1}{29\cdot3}$	$\frac{1}{23\cdot47}$
50	1466·65	880	$\frac{1}{48\cdot9}$	$\frac{1}{36\cdot7}$	$\frac{1}{29\cdot3}$
60	1759·98	1056	$\frac{1}{58\cdot7}$	$\frac{1}{44}$	$\frac{1}{35\cdot2}$
70	2053·31	1232	$\frac{1}{68\cdot4}$	$\frac{1}{51\cdot3}$	$\frac{1}{41\cdot1}$
80	2346·64	1408	$\frac{1}{78\cdot2}$	$\frac{1}{58\cdot7}$	$\frac{1}{46\cdot9}$
90	2639·97	1584	$\frac{1}{88}$	$\frac{1}{66}$	$\frac{1}{52\cdot8}$
100	2933·30	1760	$\frac{1}{97\cdot8}$	$\frac{1}{73\cdot3}$	$\frac{1}{58\cdot7}$

Or putting a for the velocity in miles per hour, v for the velocity in yards per minute, and v' for the velocity in yards per second, we have

$$v=\frac{1760\cdot a}{60}=29\cdot333a$$

$$v'=\frac{1760\cdot a}{3600}=4\cdot888a$$

And in the table, taking either of the three right-hand columns, according to the length of bearing, for instance the eighteen-inch column for a three-feet rail, we have the number of inches through which the engine or any other body would fall by the action of gravity in free space, in the time which it takes to pass over 18 inches at the given velocity, by the formula

$$s=t^2\cdot193,$$

where t is the time in seconds, and s the space in inches. Thus at 20 miles an hour, with a three-feet rail, where 18 inches are passed over in $\frac{1}{19\cdot6}$ of a second, the engine would fall during that time

$$\left(\frac{1}{19\cdot6}\right)^2\cdot193=\frac{1}{384\cdot16}\cdot193=\frac{193}{384\cdot16}=\cdot5, \text{ or half an inch.}$$

Again at 30 miles an hour, with a 3-feet rail, 18 inches of which are passed over in $\frac{1}{29\cdot3}$ of a second, the engine during that time would fall

$$\left(\frac{1}{29\cdot3}\right)^2\cdot193=\frac{1}{858\cdot49}\cdot193=\frac{193}{858\cdot49}=\cdot225,$$

or not quite a quarter of an inch.

And denoting by t and s the time and space as above, we have conversely, knowing the space an engine would have to fall, for instance, through a bad joint, the distance the engine would pass over without touching the lower rail, by the formula

$$t=\sqrt{\frac{s}{193}}.$$

Thus when $s=\cdot225$, we have

$$t=\sqrt{\frac{\cdot225}{193}}=\sqrt{\cdot001166}=\cdot0341=\frac{1}{29\cdot3}$$

of a second, in which, at 30 miles an hour, we find by the table the engine would pass over 18 inches of the lower rail without touching it, describing in its fall a parabola modified by the effect of the springs on the engine.

This has been put to the test of experience by bending a rail nearly half an inch, and then painting it. An engine and train of carriages were then run over it, none of the wheels of which touched the paint for 22 inches. This affects a railway in three ways. First, when the engine has to fall, through a bad joint, the rail which it leaves being higher than the rail it is coming upon, the increased momentum from the fall will here occasion a larger deflection than ordinary, and a consequent inclined plane against the engine, from the time it comes on the rail till it passes the next chair. Secondly, when a rail is permanently bent, where the resistance on the second or rising part of the rail will be less than in the first case. And thirdly, when the rail is simply deflected by the weight of the engine, and restores itself to its original level when that weight has passed; here the effect will be least of all, the rail taking the form of a receding wave before the wheel, and a following wave after it.

In the second case, where the rail is permanently bent, the formula for the space the engine would fall will be

$$s=\frac{H}{L}\cdot 193\cdot t^2,$$

where H is the height of the plane, and L its length, s and t being as before. For instance, if the bend is ·1 of an inch in a 3-foot rail, we have $s=\frac{1}{180}\cdot 193\frac{1}{858\cdot 49}=\cdot 00125$ of an inch, at 30 miles an hour, and $s=\frac{1}{180}\cdot 193\cdot\frac{1}{384\cdot 16}=\cdot 00278$ of an inch at 20 miles an hour, or $\frac{1}{380}$ of an inch at 20, and $\frac{1}{800}$ of an inch, at 30 miles an hour, would be descended by the engine by the effect of gravity, in the same time that

steam and gravity together take it along 18 inches of the rail.

Let us next suppose we have steam enough to carry the engine along at a velocity so great, that gravity will not bring it down the ·1 of an inch perpendicular, whilst steam carries it along the 18 inches horizontal, we shall find this velocity to be at and above 44 miles an hour, for it takes $\frac{1}{43}$ of a second for a body to fall one-tenth of an inch by the effect of gravity, and $\frac{1}{43}''$: 18 in. $=3600''$: 44 miles; hence at 44 miles an hour, and at all velocities above it, the engine, after arriving on the rail, bent one-tenth of an inch in the middle, and forming two planes, will no longer touch the rail till after it has passed the middle of it, and velocities of 60 miles an hour have been attained.

In the third case, the engine does not go down a plane, as above, but has to make its own curve through its weight, deflecting the rail. The necessity then of knowing the laws of deflection is such, that no idea can be formed of the effects these importants matters will have on the economy of railroads; yet we have up to the present day positively no data to go upon, which will lead us at all near the truth; and railways are constructing, at a cost very little short of seven millions, without the means having been taken to put such essential points as these out of the pale of doubt and uncertainty, which could be done by a few well conducted experiments. We know, for example, that in an iron bar, if $l=$ the half length, $x=$ any variable distance, $y=$ the corresponding depth, and $\Delta=$ the sine of the elementary deflection, the sum of the deflections when $x=l$ is $\int\frac{x^2}{y^3}\delta x\ \Delta$ for a parallel bar, and $\int\frac{x^2\delta x\Delta}{(a+bx)^3}$ for a fish-bellied rail, in which latter expression $a=$ the least depth, and $b=$ the difference of the depths divided by the half length.

In some cases, where we have good experiments, the mode by which they have been calculated, in order to ge-

neralize and render available their results, is inaccurate, and the effect may be shewn by the following table, giving the deflection of rails, with three tons' weight on the middle of them, each column deduced from the same set of experiments, differently computed, and varying to an enormous degree.

Length of bearing in inches.	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*
33	·024	·026	·03	·02357	·0272	·0286	·072	·0858
42	·037	·050	·06	·047	·0538	·0569	·111	·1707
45	·041	·063	.072	·056	·064	·068	·123	·204
57	·064	·122	·139	·108	·123	·131	·192	·393
60	·074	·150	·171	·1335	·153	·162	·222	·486
69	·082	·210	·241	·188	·216	·228	·246	·684

Column *a* gives the deflections at 3 tons, deduced from the experiments by the experimenter, except for the sixty-inch, which is derived from the fifty-seven inch bearing. Column *b* gives the deflections derived from the formula given by the experimenter as the results of the same experiments. Column *c* gives the deflections from this formula, recomputed by another person. Column *d* gives the deflections computed from another formula given by the experimenter. Column *e* gives the deflections in column *d*, computed by another person. Column *f* gives the mean of columns *c* and *e*, which appears to be the best approximation we have. Column *g* and *h* give the dĕflections for 9 tons' weight, the first being derived from column *a*, and the second from column *f*, the difference in the longest bearing 69 inches, being nearly 3 to 1.

With this lamentable uncertainty in the data for a deduction of such importance as that of a deflection in the rails causing an engine to be constantly ascending an inclined plane, there is no hope of arriving at any commonly

accurate results. For instance, if we take the bearing of 5 feet, which Mr. Barlow gives, as occasioning the ascent of a plane of 1 in 1875, the deflection, with 3 tons' weight, being ·064, and substitute for ·064 the deflections in columns *a* to *f* successively, we have as follows:—

		Deflection.		Consequent Planes.
By column *a*	...	·074	...	1 in 1621
— *b*	...	·150	...	1 in 800
— *c*	...	·171	...	1 in 702
— *d*	...	·1335	...	1 in 899
— *e*	...	·153	...	1 in 791
— *f*	...	·162	...	1 in 741

In which there is more than two and a-half to one difference in the results, all of which are drawn from one set of experiments, whilst at the same time the probability is, that the planes ought to turn out less steep instead of being more so.

From the effects which arise in consequence of deflection, it will be well worth considering what advantages are derived from the use of felt under the chair. If the rail was perfectly stiff, then, when the engine came over a chair, and compressed the felt, it would afterwards have to go up an inclined plane, through the rail being depressed at the block it had just passed over; and this would continue to take place till the engine arrived towards the next block, when it would depress the rail again in a similar way, and thus its course would be continually up a partially rising plane, the assistance downwards being almost insensible.

But as every rail deflects more or less, the inclination produced by this cause acts just exactly in the opposite manner to that which takes place through the depression and spring of the felt; for whilst the wheel, from the effect of deflection in the rail, descends during its passage over the first half of the rail, and ascends while going over the second half, the effect which the compression and springing of the felt has upon it, is to make it ascend a plane during

its passage of the first half, and to descend during the time it is going over the second half. The felt acting as a spring, however, is exceedingly questionable, although maintained by some persons. Its use will be found to consist more in giving a steady seat for the chair when the block is composed of hard stone, and offering a defence against the grating of the chair on the block, which will otherwise take place, producing a grinding, a loss of surface, and consequently a looseness, which, when once arrived at, rapidly increases.

From the above observations on the effects of inclined planes, we may see how desirable it is to have the blocks and sleepers placed in the most accurate manner, as respects uniformity of height. For we must recollect, that in a three-feet rail, a difference of one quarter of an inch in the height of two adjacent blocks, or, more properly speaking, in the height of the basis of two adjacent chairs, converts that three feet of rail into an inclined plane, rising 1 in 144.

With respect to placing the blocks diagonally, this is a less stable position in the line of rails than when they are placed square, for the resistance of the ground to the sinking of the block, whether conceived to be similar to a collection of springs acting under the block, or a collection of weights acting above it, must in either case be referred to the centre of gravity of each half of the block, considering it as moved by the passing weights about a line drawn through its middle at right angles to the line of the rails; that is to say, in a block two feet square, and one foot thick, there are 12 inches in the direction of the rails, 24 inches across them, and 12 inches in depth, acting on each side the axis of motion when the block is laid square, the surface of each half being 288 inches. Now, any uniform effect on these 288 square inches drawn into the distance of their centre of gravity from the axis of motion, gives for the stability of each half 1728. Any uniform effect on the 288 inches of a diagonal half block will give a less number; for

the distance of the centre of gravity from the axis of motion was 6 inches in the square block, but it will be only 5·65682 in the diagonal, being 1-3d the altitude of the triangle, and hence we have only 1629·16416 for the stability in the direction of the rails. The diagonal block will consequently have its maximum resistance to sinking at 45° from the line of the rails, or in the position where stability is least required. Circular blocks have been proposed in order to get equal resistance in all directions, but the gain would not be equal to the extra expense, and the stability, although a trifle more than that of the diagonal block in the line of the rails, is less than that of the square one; for the area, as before, being 567 square inches, $=\cdot785398d^2$, and d being the diameter, we have $d=\sqrt{733\cdot386}=27\cdot0811$, and the radius $=13\cdot5405$, and as the arc is to the chord, so is $\frac{2}{3}$ radius to the distance of the centre of gravity from the centre, or $3\cdot14159\times13\cdot5405 : 27\cdot0811=9\cdot02703 : 5\cdot74678$ inches, and $5\cdot74678\times288=1655\cdot=07264$ for the resistance.

We have experimented on the two positions of the blocks, and found that when placed diagonally, there was rather more resistance to lateral motion than when placed square, and they are more conveniently got at to repack in the former position than they are in the latter; but when placed as close as they ought to be, in order to form an economical road, the diagonal position is inadmissible.

It will be seen from the following tables which we have computed, that instead of increasing the bearings from three feet, if we study economy, we should reduce it; and as we have in these tables taken into account all ordinary variations in the elements of expenditure, we must consider it proved that except under very extraordinary circumstances, the nearer the supports are brought together up to the limits here given, the cheaper will the railway be made, whilst of course it will possess more stability, in proportion to the number of resisting bodies which have to be moved, before it can be thrown out of its proper position.

TABLE I.—*Comparative Cost of Long and Short Rails.*

Length of rail in feet.	lb. per yard.	lb. per rail.	Cost of block.	Price per rail.		Price per block.		Total price.		Price of one yard.	
				s.	d.	s.	d.	s.	d.	s.	d.
2	40	26·66	·4	3	4	8	0	11	4	17	0
2¼	45	33·75	·425	4	2½	8	6	12	8½	16	11·50
2½	50	41·66	·45	5	2½	9	0	14	2½	17	0½
2¾	55	50·42	·475	6	3½	9	6	15	9½	17	2½
3	60	60·00	·5	7	6	10	0	17	6	17	6
3¼	65	70·42	·525	8	9½	10	6	19	3½	17	9¾
3½	70	81·66	·55	10	2½	11	0	21	2½	18	2
3¾	75	93·75	·575	11	8½	11	6	23	2½	18	6¾
4	80	106·66	·6	13	4	12	0	25	4	19	0
4¼	85	120·42	·625	15	0½	12	6	27	6½	19	4¼
4½	90	135·00	·65	16	10½	13	0	29	10½	19	11
4¾	95	150·42	·675	18	9	13	6	32	3½	20	4¾
5	100	166·66	·7	20	10	14	0	34	10	20	10¾

TABLE II.—*Weight of Rail when the Prices per Yard are equal.*

Length of rail in feet.	Price per yard.		Price of block per yard.		Price of rail per yard.		Weight of rail which costs that price.
	s.	d.	s.	d.	s.	d.	
2	17	0	12	0	5	0	40
2¼	17	0	11	4	5	8	45·33
2½	17	0	10	9·6	6	2·4	49·6
2¾	17	0	10	4·36	6	7·64	53·09
3	17	0	10	0	7	0	56
3¼	17	0	9	8·31	7	3·69	58 46
3½	17	0	9	5·14	7	6·86	60·57
3¾	17	0	9	2·4	7	9·6	62·4
4	17	0	9	0	8	0	64
4¼	17	0	8	9·88	8	2·12	65·41
4½	17	0	8	8	8	4	66·66
4¾	17	0	8	6·32	8	5·68	67·786
5	17	0	8	4·8	8	7·2	68·8

TABLE III.—*Effects of one-sixth decrease in the price of iron on the comparative cost of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price of 1 yard.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
2	2	9¼	8	0	10	9¼	16	1·875
2¼	3	6¼	8	6	12	0¼	16	0·33
2½	4	4	9	0	13	4	16	0·1
2¾	5	3	9	6	14	9	16	1·1
3	6	3	10	0	16	3	16	3
3¼	7	4	10	6	17	10	16	5½
3½	8	6	11	0	19	6	16	8½
3¾	9	9¼	11	6	21	3¼	17	0¼
4	11	1¼	12	0	23	1¼	17	4
4¼	12	6½	12	6	25	0½	17	8½
4½	14	0¾	13	0	27	0¾	18	0½
4¾	15	8	13	6	29	2	18	5
5	17	4¼	14	0	31	4¼	18	9¾

TABLE IV.—*Effect of a decrease of one-eighth in the price of a block complete on the comparative cost of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price per yard.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
2	3	4	7	0	10	4	15	6
2¼	4	2½	7	5¼	11	7¾	15	6·33
2½	5	2½	7	10½	13	1	15	8½
2¾	6	3½	8	3¾	14	7¼	15	11¼
3	7	6	8	9	16	3	16	3
3¼	8	9½	9	2¼	17	11¾	16	7¼
3½	10	2½	9	7½	19	10	17	0
3¾	11	8½	10	0¾	21	9¼	17	5
4	13	4	10	6	23	10	17	10½
4¼	15	0½	10	11¼	25	11¾	18	4
4½	16	10½	11	4½	28	3	18	10
4¾	18	9½	11	9¾	30	7¼	19	4
5	20	10	12	3	33	1	19	10¼

TABLE V.—*Effect of a decrease of one-sixth in the price of the rail, and one-eighth in the price of the block, on the comparative cost of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price per yard.	
	s.	d.	s.	d.	s.	d.	s.	d.
2	2	9¼	7	0	9	9¼	14	7·875
2¼	3	6¼	7	5¼	10	11½	14	7·333
2½	4	4	7	10½	12	2½	14	7·8
2¾	5	3	8	3¾	13	6¾	14	9½
3	6	3	8	9	15	0	15	0
3¼	7	4	9	2¼	16	6¼	15	3
3½	8	6	9	7½	18	1½	15	6½
3¾	9	9¼	10	0¾	19	10	15	10½
4	11	1¼	10	6	21	7¼	16	2½
4¼	12	6¼	10	11¼	23	5¾	16	6¾
4½	14	0¾	11	4½	25	5¼	16	11½
4¾	15	8	11	9¾	27	5¾	17	4¼
5	17	4¼	12	3	29	7¼	17	9¼

TABLE VI.—*Effect of a decrease of one-sixth in the price of the rail, and of one-fourth in the price of the block, on the comparative cost of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price of 1 yard.	
	s.	d.	s.	d.	s.	d.	s.	d.
2	2	9¼	6	0	8	9¼	13	1·875
2¼	3	6¼	6	4½	9	10¾	13	2·33
2½	4	4	6	9	11	1	13	3½
2¾	5	3	7	1½	12	4½	13	6
3	6	3	7	6	13	9	13	9
3¼	7	4	7	10½	15	2½	14	0½
3½	8	6	8	3	16	9	14	4¼
3¾	9	9¼	8	7½	18	4¾	14	8½
4	11	1¼	9	0	20	1¼	15	1
4¼	12	6½	9	4½	21	11	15	5½
4½	14	0¾	9	9	23	9¾	15	10½
4¾	15	8	10	1½	25	9½	16	3½
5	17	4¼	10	6	27	10¼	16	8½

TABLE VII.—*Effect of an increase of one-sixth in the price of the rail, and a decrease of one-sixth in the price of the block, on the comparative distance of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price per yard.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
2	3	10·666	6	8	10	6·666	15	10
2¼	4	11·0625	7	1	12	0·0625	16	0·833
2½	6	0·915	7	6	13	6·915	16	3½
2¾	7	4¼	7	11	15	3¼	16	8
3	8	9	8	4	17	1	17	1
3¼	10	3¼	8	9	19	0¼	17	6¾
3½	11	11	9	2	21	1	18	0
3¾	13	8	9	7	23	3	18	7¼
4	15	6½	10	0	25	6½	19	2
4¼	17	6¾	10	5	27	11¾	19	9
4½	19	8¼	10	10	30	6¼	20	4¼
4¾	21	11¼	11	3	33	2¼	20	11¾
5	24	3½	11	8	35	11½	21	7

TABLE VIII.—*Effect of a decrease of one-sixth in the price of the rail, and an increase of one-sixth in the price of the block, on the comparative cost of long and short rails.*

Length of rail in feet.	Price per rail.		Price per block.		Total price.		Price of 1 yard.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
2	2	9½	9	4	12	1½	18	2¼
2¼	3	6¼	9	11	13	5¼	17	11·0
2½	4	4	10	6	14	10	17	9·6
2¾	5	3	11	1	16	4	17	9·8181
3	6	3	11	8	17	11	17	11
3¼	7	4	12	3	19	7	18	1
3½	8	6	12	10	21	4	18	3½
3¾	9	9¼	13	5	23	2¼	18	6½
4	11	1¼	14	0	25	1¼	18	10
4¼	12	6½	14	7	27	1½	19	1½
4½	14	0¾	15	2	29	2¾	19	5¾
4¾	15	8	15	9	31	5	19	10
5	17	4¼	16	4	33	8¼	20	2½

From these tables, it will be evident that the prices of the materials comprising the permanent way, will very rarely be greater or less than the rates at which they are given; and that consequently it is no longer a question, as far as expense is concerned, which is the best mode of laying a railway.

In these tables we have exhibited each item separately, in order that the component parts of the expense may be seen, as well as the gross sum. The right-hand column in each table shews the price of one yard of single rail, or one-fourth the price of two lines of rails. In Table I. the rails are taken at L.14 per ton, to include freight and carriage, and 10s. as the price of a block, containing five square feet of stone, with its chair, &c., complete, including carriage; but in each table the cost of laying the way is excluded. This price for the block will give 8s. for a two-feet rail, which may be thus divided:—

	s.	*d.*	
2 treenails at L.4 per 1000,	0	$0\frac{1}{2}$	Including all charges to the place of delivery.
2 spikes, at L.19 per ton, 2400 to the ton,	0	$3\frac{3}{4}$	
1 piece of felt,	0	$0\frac{1}{4}$	
1 wedge,	0	$1\frac{1}{4}$	
1 chair, at L.9 per ton, weight 20 lb.,	1	7	
1 block, 1 foot thick, and 1 foot 10 inches each side,	5	$11\frac{1}{4}$	
	8	0	

In calculating for any intermediate lengths not in the table, for every tenth of a foot increase in the length of bearing, add 2 lbs. to the weight per yard, and 2·4d. to the price per block, in each case to the tabular number, in a line with that length to which the addition is made. Thus, for 2·2 feet say 44 lbs. per yard, and 8s. 4·8d. for the block; and when a different price is taken for the block, increase it $\frac{1}{26}$th for each 3 inches of increase in the length of the rail, and proportionally for all other lengths.

The minimum price in Table I. is when the length of bearing is 2·2 feet, being then 16s. 11·45d. per yard single rail.

Table II. is computed to shew that if we take the same proportion for the blocks as in Table I., and at the same time keep the total expense per yard the same at all lengths, we shall have too little money left to get an efficient rail; it is calculated, by turning the price of the blocks in Table I. into the price per yard, and subtracting this from 17s., the remainder will be the price of the rail per yard, which, at $1\frac{1}{2}$d. per lb., will shew how heavy a rail can be got for that price. Thus, we see that we can only have 8lbs. more in a five-feet rail than we ought to have in a three-feet; besides which, we cannot get up to our standard, namely, 60 lb. at three-feet bearings.

Table III. shews the comparative cost with the rails at $1\frac{1}{4}$d. per lb., or L.11, 13s. 4d. per ton, and the minimum laying between $2\frac{1}{4}$ and $2\frac{3}{4}$ feet of bearing, we shall shew how to ascertain where it exactly is, which method answers for the other similar tables. Let us first take 2·6 feet for the length of bearing, and adding, as before directed, 2 lbs. for this additional tenth of a foot, to the weight for 2·5 feet, we get 52 lbs. per yard, as the weight at 2·6 feet, and 3 feet : 52 lbs. = 2·6 feet : 45·066 lbs. for the weight per rail, which at $1\frac{3}{4}$d. per lb. is 56·332d. The price of a block for a 2·5 feet length is 108d., and adding 2·4, we get 110·4d. for the block at 2·6 feet; and this added to the price per rail, gives 166·732d. for the total price per rail, or nearly 13s. $10\frac{3}{4}$d. Thus, as 2·6 feet : 166·732d. = 3 feet : 16s. 0·38d. for the price per yard complete of single rail, whereas at 2·5 feet it is 16s. 0·1d.; hence the minimum lies between 2·25 and 2·5 feet, and not between 2·5 and 2·75 feet.

Resuming our trial with 2·4 feet, we have 45 + 3 = 48 lbs. for the weight per yard at 2·4 feet, and 3 feet : 48 lbs. = 2·4 feet : 38·4 lbs. per rail, which at $1\frac{1}{4}$d. per yard, costs 4s. The price of the block at 2·25 feet is 102d., and adding

3 6d. we get 105·6d. for the block at 2·4 feet; that added, to the price of the rail, gives a total of 12s. 9·6d., and as 2·4 feet : 153·6d. = 3 feet : 192d. or 16s. 0d., whereas the price at 2·5 feet is 16s. 0·1d. In the same way we may repeat the calculation till we arrive at what extent of accuracy we choose.

Having seen the effect which lowering the price of iron has, we know that by raising it, we should find it cheaper to put the blocks close together than our first table indicated; thus, if iron is $1\frac{3}{4}$d. per lb., we have for 2-feet rails 3s. 10·666d. as the price of the rail, and 11s. 10·666d. as the price of the rail and block complete, which gives us 17s. 10d. as the price per yard, whereas with 2·25 feet rails it would be 4s. 11·0625d. the rail, and 13s. 5·0625d. for the rail and block, or 17s. $10\frac{3}{4}$d. per yard.

Table IV. shews the effect of cheaper blocks on the total cost at each length of bearing; it begins at 7s. per block, and increases $5\frac{1}{4}$d. or $\frac{1}{20}$th, for each 3 inches of increase in the length of the rail. The price of rails will never materially differ in any part of England, the freight being the principal variable quantity, but the price of blocks will alter in a very great degree, and the effect of this may be shewn; take, for example, 2s. 8d. as the price of one for a two-feet bearing, and we know they have been procured cheaper; adding to this, as we have done before, 2s. for the other items connected with the block, we get 4s. 8d. as the price of a block complete, and the price of the rail being 3s. 4d., the total price is 8s. per rail, or 12s. per yard. In the same way we have 12s. 6d. per yard at $2\frac{1}{4}$-feet bearings; 13s. 1d. at $2\frac{1}{2}$ feet; 13s. 7d. at $2\frac{3}{4}$ feet; 14s. 2d. at 3 feet; and 18s. 11d. at 5 feet; hence in a railway 31 miles long, we shall find the saving, by having the blocks at two feet apart, L.75,293, viz.

31 miles at 5 feet,.............	L.206,237
„ „ 2 feet,.......	130,944
	L.75,293

And as an useful approximation to this calculation, we may take each farthing per yard increase of cost in the total price per yard of single rail, to give L.7·3333 per mile of double line, or in the above instance, there being 332 farthings between 12s. and 18s. 11d., we have $7·3333 \times 332 \times 31 =$ L.75,474.

As we are obliged to place our supports close together, to get a minimum cost when the blocks are less in price than the cost we first assumed, so we shall find that when greater, we must increase their distance. For instance, if a block for a two-feet bearing costs 9s., the cost per yard of block and rail complete will be 18s. 6d.; at $2\frac{1}{4}$ feet, 18s. $4\frac{1}{2}$d., and at $2\frac{1}{2}$ feet, 18s. $4\frac{3}{4}$d., the minimum being between $2\frac{1}{4}$ and $2\frac{1}{2}$ feet.

We have next to see what will be the effect when the rail and block are both either greater or less than in Table I. This divides itself into three branches; first, when they decrease or increase in an equal ratio; secondly, when the rail decreases or increases in a greater ratio than the block; and, thirdly, when the block decreases and increases in a greater ratio than the rail.

In the first case, the ratio of the price per yard will remain evidently the same as in Table I. Thus, if both rail and block are reduced in price $\frac{1}{6}$th, we shall have at 2 feet, the price per yard, 14s. 1·875d.; at $2\frac{1}{4}$ feet, 14s. 1·66d. per yard; and at $2\frac{1}{2}$ feet, 14s. 2·4d.; hence the minimum is as before at about 2 feet 2 inches, and the same will hold under any other increase or decrease, the ratio in rail and block being equal.

For the second case, when the rail decreases in price in a greater ratio than the block, Table V. shews the corresponding effect, and the minimum will be found again at about 2 feet 2 inches, for at that distance we have 44 lbs. for the weight of the rail per yard, or 32·267 lbs. for the weight per rail, which at $1\frac{1}{4}$d. per lb. is 40·334d.; for the block, if ·25 of a foot, increases the price $5\frac{1}{4}$d., then ·2 of a

foot will increase it 4·2d., which added to 84d., the price at 2 feet, gives 88·2d. for 2·2 feet. Hence the total price of rail and block is 10s. 8½d., or 14s. 7·27d. per yard, which is rather less than at 2¼ feet.

It will be found, in like manner, that the effect of an increase of price in the same ratio will not affect the minimum; for example, with an increase of $\frac{1}{6}$th in the price of the rail, and $\frac{1}{6}$th in the price of the block, we have at 2 feet the rail 3s. 10·666d., the block 9s.; total, 12s. 10·666d., or 19s. 4d. per yard. With 2¼ feet, the rail will be 59·065d., the block 114·75d.; total, 14s. 5·815d., or per yard, 19s. 3¾d. With 2½ feet the rail will be 72·915d., the block 121·5d.; total, 16s. 2½d., or per yard 19s. 5·299d.; and with 2·2 feet, we have the rail 56·466d., the block 113·376d.; total 14s. 1·842d., or per yard, 19s. 3·6d., or rather less than at 2¼ feet.

For the case where the rail increases or decreases in a less ratio than the block, Table VI. shews the comparative effect on the minimum, which is here at about 2 feet, with a decrease in the prices; for trying 2·2 feet, we get for the rail 40·334d., the block 75·6d.; total, 115.934d., or per yard, 13s. 2·09d.; and at 2·1 feet, we have for the rail 36·75d., the block, 73·8d.; total, 110·55d., or per yard 13s. 1·93d.

When there is an increase of $\frac{1}{6}$th in the price of the rail, and ¼th in the price of the block, we have for 2-feet bearings, the rail, 46·66d., the block, 120d.; total, 166·66d., or per yard, 20s. 10d.; for 2¼ feet, we have, rail, 59·0625d., block, 127.5d.; total, 186·5625d., or per yard 20s. 8.75d.; for 2½ feet, the rail is 72·915d., the block, 135d.; total, 207·915d., or per yard, 20s. 9·498d. Hence the minimum is at 2¼ feet, for at 2·3 feet the rail is 61·7165d., the block 129d.; total, 190·7168d., and the price per yard, 20s. 8·76d.; and at 2.2 feet, the rail is 56·4665d., the block, 126d.; total, 182·4665d., and the price per yard, 20s. 8·81d.

We have now only left the cases where the price of the

rail increases, while that of the block decreases; the effect of this is shewn in Table VII.; and when the price of the rail decreases, whilst that of the block increases, this is given in Table VIII. In Table VII. the minimum expense is at the distance of 2 feet, and in Table VIII. at $2\frac{3}{4}$ feet, this being the greatest distance yet obtained; hence cheap rails and very dear blocks are the only conditions which will warrant a distance at all approaching to those now in use; $2\frac{3}{4}$ feet appearing to be the limits under any ordinary prices, and in general only $2\frac{1}{4}$, while in some instances 2 feet only should be taken, in order to lay down a railroad at the minimum expense, as far as the cost of the permanent way is concerned.

In Table VIII. we do not know on which side of $2\frac{1}{2}$ feet the minimum expense will be; we shall therefore, in order to complete the inquiry, investigate this as we have done in the other cases. Taking, then, 2·6 feet, we get 52 lbs. per yard for the weight, or 45·065 lbs. per rail, costing at $1\frac{1}{4}$d. per lb. 56·332d.; for the block we have as ·25 feet : 7d. =·1 foot : 2·8d., or 10s. 8·8d.; total, 185·132d., or per yard, 17s. 9·1d., being rather more than the price at 2·5 feet. Trying now 2·4 feet, we have 48 lbs. per yard, or 38·4 lbs. per rail, costing 48d., and for the block 119d., the price at $2\frac{1}{4}$ feet plus 4·2d., the proportion for ·15 feet, or 123·2d.; total, 171·2d., or per yard, 17s. 10d. which is more again than at 2·5 feet; the minimum price will therefore be very near 2·5 feet, but rather more if any thing.

It now remains for us to shew, why the particular rate of increase and decrease in the size of the rail and block, which we have given in the tables, has here been assumed. And, first, of the blocks. Every person, when calculating this effect of prices for any particular railway, will of course take into consideration the cost of rails, blocks, and sleepers for the railway in question; and as the rate of increase we have given, viz. one-fourth in the price of the block chair, and all appurtenances complete for each foot in-

crease in the length of the rail, is more than what is necessary rather than less, and as a decrease in the price of the blocks will lead to shortening the rails still more, it will be seen that any error will be on the safe side. It will most probably be found in practice, that whatever the distance between the supports may be, the same absolute surface should be preserved in every case; for although it has been said that each block, be its distance what it may, has but to support a certain weight passing over it, yet this is not a correct mode of reasoning, because it has to support that weight for a longer time, when the distance between each is increased, which is the same thing as having to support a greater weight. For instance, with blocks five feet apart, if we only took them at four square feet each for the intermediate ones, and five square feet for the joints, we should have 183040 square feet, supporting the train for one hour, at a velocity of twenty miles per hour, whilst the same sized blocks at three-feet bearings would afford 281600 square feet to support the train for the same time at the same speed, being a difference in favour of the short bearings of 98560 square feet, or more than one-third. Our increase in the tables is rather less than would be required to preserve the same absolute surface.

With respect to the increase in the weight of the rails which we have taken, viz. sixty lbs. per yard at three-feet bearings, as a standard, and adding or subtracting five lbs. for every three inches of increase or decrease, we can only state that we have taken this from an attentive consideration for some years of the practical effects exhibited by the rails now in use on various lines. A mathematician will say, this is following no known law. It is not, and we firmly believe that to attempt to lay down mathematical laws for the dimensions of rails would be perfectly premature, in the present state of our ignorance on this subject. Before this can be done, a complete and satisfactory set of experiments must be made, to settle the many points now in dispute; and so

much depends on the form of the rail, and the quality of the iron, that the weight and dimensions must be left to the judgment of the engineers of the respective lines, who, having their characters for ability at stake, will be influenced in every possible way to take all the necessary steps for coming to a right conclusion, and when in doubt, they will of course resort to experiment, every penny spent in which will in all probability save many pounds.

To assist in computing similar cases to those which we have above given, we may observe, that each farthing per lb. in the price of iron gives L.2, 6s. 8d. per ton, and each pound per ton gives ·428571, &c. of a farthing for the price per lb.; hence, multiplying the number of pounds and decimals of a pound in the price per ton by ·428571, will give the price per lb. in farthings and decimals.

In computing the relative strength, &c. of the various rails, the following table will be useful:—

Length of rail; inches.	Square.	Cube.	Depth of rail; inches.	Square.	Cube.
30	900	27000	$3\frac{1}{2}$	12·25	42·875
33	1089	35937	$3\frac{3}{4}$	14·0625	52·734375
36	1296	46656	4	16·	64·
42	1764	74088	$4\frac{1}{4}$	18·0625	76·765625
45	2025	91125	$4\frac{1}{2}$	20·25	91·125
48	2304	110592	$4\frac{3}{4}$	22·5625	107·171875
57	3249	185193	5	25·	125·
60	3600	216000	$5\frac{1}{4}$	27·5625	144·703125
69	4761	328509	$5\frac{1}{2}$	30·25	166·375
72	5184	373248	$5\frac{3}{4}$	33·0625	190·10937

Our experience is yet so small, that various opinions exist even amongst those best informed, as to the proper form and weight of the rail and chair, and the size of the blocks and sleepers; and there is no doubt that in a few years a material alteration will take place in all these things. Until the present time, however, there has been nothing but

change both in rails, chairs, and keys, and in the distance between the supports. Every rail should be tested before it is received from the contractor, and it should be always remembered that too much care cannot be taken with the permanent way materials. All the expense incurred in earthwork and masonry is only a means to an end, viz. the permanent road. We recommend the fish-bellied rail as possessing, weight for weight, the most strength; and this would be increased by rolling them with a lower web. How much depends on the manufacture will be apparent, when it is stated that no less than thirty rails broke on the Liverpool and Manchester railway, in the fortnight ending on the 21st January 1837.

The question of expense, as far as the present mode is concerned, is a simple problem of maximum and minimum; and it has been so treated in the preceding tables, algebraic formulæ having been omitted, to make them more generally useful. But there seems to be little doubt that with a 60-pound rail on three-feet bearings, and a block one foot thick, containing five cubic feet of stone, the increase we have given for longer bearings will not be considered as too much, when we recollect that the block has not only to support the rail, but has to sustain it against lateral deflection. When the blocks merely sink, the unusual motion of the engine and the carriages will at once detect it, and the proper remedy must be resorted to; but it might easily happen that the rails would be laterally deflected without its being observed until the train was thrown off altogether, particularly when it is taken into consideration that the carriages are still matter of experiment, and that the play of the wheels between the rails and upon the axles is not by any means a fixed quantity, and also that the whole weight of the engine acts laterally, whereas vertically that weight is divided.

A breadth of from 2 to $2\frac{1}{2}$ inches for the top of the rail, seems admitted by nearly all parties to be sufficient; less

would induce considerable wear on the engine and carriage wheels. The wear of rails on the top surface may be taken at one-thirtieth of a pound per yard per annum, and the total loss of weight at one-ninth of a pound per yard per annum; but more accurate experiments are yet required on this head, particularly as to the top surface wear; and the curious fact is yet unaccounted for, that rails laid on the ground, or keyed into chairs on blocks, but not run over by engines or carriages, oxidize considerably more than those which are used.

Six feet between each line of rails, seems also generally adopted as a convenient width; but this, of course, depends in some measure on the width between the rails, and the construction of the carriages. Should the plan of placing the wheels outside the carriages be generally adopted, a less width between the lines may suffice, but the distance would not bear to be much decreased. The width of embankments outside the rails should at least equal the width between the rails, so that, when the engines or carriages get off the line, their wheels will be so confined between the rails, that the outer one will not get off the embankment. The mode of action when an accident of this kind happens, appears not to be well understood. We frequently hear of engines being expected to drag their trains off the embankments; but this is a thing unlikely to occur often; for when an engine gets off the rails, it will generally strike so hard against the blocks and sleepers, that its velocity, independently of the shutting off the steam, or reversing the motion, will very quickly be lessened. When this takes place, the train, by its momentum, either forces the engine farther along, or, if it strike it at an angle, which is generally the case, throws it over on its side; and it is from this momentum of the train that the damage proceeds. Intermediate carriages getting off are the cause of much less danger. From the weakness of the present axle-guards,

however, these generally break when the wheels strike the blocks or sleepers ; and there is a great want of strength in the second and third-class carriages. We have known four of these, fortunately empty, crushed into toothpicks when a collision took place.

The following formula will enable manufacturers of fish-bellied rails to fit their rolls to any required size of rail. Thus, for three-feet lengths of bearing. In figure 10.

Let $r = \text{CD} =$ the radius of the rolls EF and mn.

$d =$ maximum depth of rail.

$d' =$ minimum depth.

$e = \text{CB} =$ distance of real and false centres $= \dfrac{d+d'}{2}$.

$z =$ the angle LCD.

$g = 2re$.

$k = r^2 + e^2$.

$x =$ the abscissa in inches $\}$ of the rail.

$y =$ the ordinate in inches $\}$ of the rail.

$h =$ BI.

We then have $h = \dfrac{2r+d+d'}{2}$,

and $y = h - \sqrt{k + g . \cos z}$ in the first quadrant of the roller, or from 0° to 90°, or from 1 to 9 inches in a three-feet rail, and $y = h - \sqrt{k - g . \cos z}$ in the second quadrant, or from 9 to 18 inches ;

but $z = \dfrac{2r . 3,14159}{360} . 10x = 1° . 10x$;

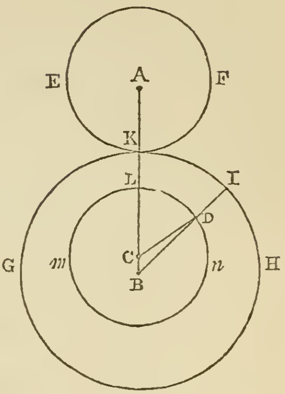
hence $y = \sqrt{k \pm g \cos\left(\dfrac{22 . 3,14159}{360} . 10x\right)}$ for every inch of x,

or $y = h - \sqrt{k \pm g \cos\left(\dfrac{r . 6,2831852}{360} . 10x\right)}$,

or $y = h - \sqrt{k \pm g \cos(r . ,0174533 . 10x)}$.

The rolls EF and *mn* should be both equal, and likewise equal to the required length of the rail between the bearings, which, as the above formula stands, is 3 feet, but having the length, breadth, and depth of any required rail given, the size of the rolls may be determined; for their circumference will always be equal to the given length of rail between the bearings, viz. 3, 4, or 5 feet, as the case may be, and all the rest is got from the above equation, which is general for all sizes, by merely noting, that when the length is any other than 3 feet, $\frac{180}{a} . x$, must be substituted for $10x$; where a equals the number of inches of half the length of the rail between the supports. Thus, for instance, for a five-feet rail the part in the final equation within the brackets will be $(r . ,017453 . 6x)$. The natural cosines are to be used, and g is to be applied although the cosine may $= 0$.

Fig. 10.



A fish-bellied rail, 50 lbs. to the yard, and with depths of 5 inches maximum and 3·8 inches minimum, compared with a parallel rail of the same weight, and the depth due to that weight, namely, 4·4 inches, each laid at three feet bearings, and having the thickness of their ribs and the form of their heads exactly similar, will be deflected, as the numbers 1881 for the fish-belly, and 2282 for the equivalent parallel; that is to say, a thickness of iron of about 3-10ths of an inch, must be added to the parallel rail in order to make it equal to the fish-belly. This proposition will nearly shew the gain obtained by the use of fish-bellies for all the usual lengths of bearing, and may be taken at 11 to 9, since, in all cases, it is stiffness which is so essentially required. Mere strength will always be had with the sizes now generally adopted; and

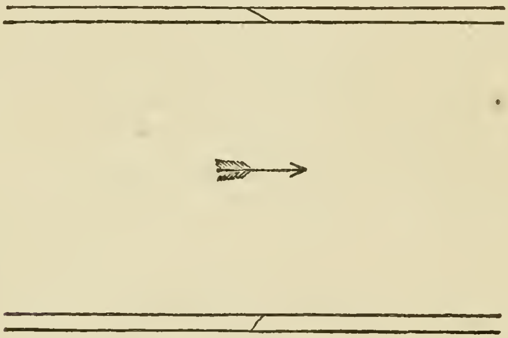
it is consequently against deflection which we have to guard, at the same time looking to economy, and not expending immense sums of money unnecessarily, as has been done in purchasing rails much heavier than are required. So much, however, depends on the quality of the iron, that we would strongly recommend every rail to be thoroughly tested when received from the manufacturer, and the results in each case registered. This would soon enable such a valuable collection of facts to be made, as that all hypothesis would cease; whereas, hitherto, there have been such discrepancies between experiments made by persons of the first eminence, that, practically, the subject is involved in as much uncertainty as ever.

Wooden sleepers, which should be laid on all embankments till they are thoroughly consolidated, ought to be wide and long, and it will not be found too much to give them ten feet in length and one foot in width for a three-feet bearing, having a proportional increase and decrease at any other bearing. The cheapest way will be to buy the sleepers in the round, and have them ripped in two by circular saws of about three feet in diameter, or even more, and with all the teeth broken off except every third or fourth. This will prevent the saw from choaking, and, in a great measure, from heating, which occasions the instrument to buckle, as it is termed. The boring of the blocks should also be done by machinery before they are delivered to the contractor, and a proportional decrease be made in his charge for laying the permanent way; and if the company do not perform this part of the work, the contractor will find it much to his interest to set up a machine for himself, if his contract exceed half a mile in length.

Various have been the opinions respecting the kind of joint by which the rails are connected, or, more properly speaking, respecting the shape of their ends; but this diversity of opinion ought not to have existed, and has only been a consequence of our want of experience on the sub-

ject. It stands to reason, and has been found to be a fact, that butt joints, that is to say, when the ends of the rails are at right angles to their length, will always occasion a shock in passing over them, even if ever so well fitted; and if, as is too generally the case, no regard is had to the temperature in laying the way, wide gaps will be found at each joining, particularly in winter. Half-lap joints are much preferable to butts, and greatly diminish the shock, but are still liable to objection; in the first place, through their weakening the rail; and, in the second, for still giving a very unpleasant jar to the carriages, although in a less degree than the butts. If they are laid right and left, as shewn below, it will improve them for diagonal joints. The form of joint we should recommend is given in fig. 11,

Fig. 11.



in which the arrow shews the direction of the train. The slope of the joint must be placed exactly contrary upon the other line of rails, so that the wheels never meet the pointed end of the rail, but always run off. It then needs no other care, than that the point should of the two be the most prominent towards the wheel, and, if it is not so, the joining rail should be taken down a little with a file.

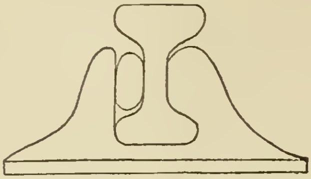
Treenails should be made of good heart of oak, well seasoned, until thoroughly dry, or of African teak, straight-grained; and each treenail should be cylindrical, one inch and a half in diameter, and six inches in length, having a cir-

cular hole, half an inch in diameter, and six inches in length, bored through the centre for the insertion of the iron spike to fix the chair. They are sometimes made by being turned in a lathe, and are also done by being passed through a cutting knife; but by whatever process they are brought to the required shape, regard should in all cases be had to the grain of the wood, which should in every instance be completely followed. The most usual way of contracting for these is, at so much per thousand, stating the place of delivery; but if a steam-engine be used to make wooden keys, it can also work lathes for the treenails, which, in that case, will be no cost, except for labour, as, in cutting up planks for the wedges, plenty of waste pieces will be found to make the treenails A plan has grown into use on some railways, of dropping the treenails loose into the hole of the block, and then driving the spike in and splitting them; but this is not so good as driving them in tight. Oak spikes have formerly been much used, and have been known to last twenty years; we should not, however, recommend them, with the rate of speed that has now been attained.

The best form of chair is a subject requiring deep consideration, and on which engineers of eminence are by no means decided; we have, therefore, given several drawings of those which are most approved. The leading distinctions are, whether the rails have been keyed in by iron or by wood. The latter method, indeed, is almost indispensable when the rails have lower webs; for, as it would by no means do to have the chair following the shape of the rail, as in that case it must always be detached from the block whenever it is required to take the rail out of it, this consequence ensues, namely, that the opening in the chair must be as large as the lower web of the rail. A chair of this kind, with its wooden key, is shewn in fig. 12. In every mode of keying it must always be remembered, that the intention is merely to keep the rail down in the chair, and not to attempt to confine it from longitudinal

motion. The right way of making these wedges is an es-

Fig. 12.



sential thing, and should be done by the company. The original mode was to purchase oak plank, thoroughly seasoned, and of the thickness required. If it be not seasoned in the most complete manner, it will not answer; but this process may be hastened by steaming it in a tank, with a pressure of about 12 lbs. on the square inch. When it is thoroughly seasoned it should be removed into a drying-house, having hot air flues under the floor, made of iron pipes, where all moisture must be extracted; and when thoroughly dry, it is cut into the proper scantling, and into thirteen-inch lengths, each of which when complete is cut into two for joint chairs, or three for intermediate chairs. They are first prepared by joiners to the right shape for going through the cutters; a joiner will prepare about 100 in a day. The cutters are composed of four blocks of iron, fixed one over the other, with openings between each of about one inch, sloping downwards. In the centre of the three lower blocks are steel cutters, the lower one being exactly the shape of the key, and the others above gradually larger. The key is put in at the top, and forced through by a lever about seventeen feet in length, brought down by a chain and crab winch, with eighty teeth in the wheel and ten in the pinion. Three men will work this, and in ten hours will cut 500 pieces, thirteen inches long, to the required shape. The shavings come through the spaces between the iron blocks, and by the gradual cutting, each one taking off a part, the knots in the wood go through without breaking, and the key comes out perfectly smooth.

The next process is compressing them, which is done by

forcing them through an iron block, ten inches thick, with twelve holes in it, 3-16ths of an inch smaller than the key at the lower part, and tapering to the top to admit the key. They are forced through by the ram of an hydraulic press, worked by two pumps, one of an inch and-a-half in diameter, the other of one inch, the diameter of the ram being nine inches, and the safety valve loaded to about nine hundred tons. Four men work the large pump, and two the small. They will get through 900 per day. A little rough grease is first rubbed over them. They are then cut into two or three, or more, in the proper proportion, according to the relative number of joints to intermediate chairs, and packed up in bags, care being taken to keep them in a dry place.

This method of manufacture has been much improved by the erection of an engine on the London and Birmingham railway, by which circular saws, running from 900 to 1100 revolutions per minute, rip the plank into scantling, and afterwards cross-cut the thirteen-inch lengths. Two more cutters were adapted on the top of the other four, but gradually larger. These took in the thirteen-inch lengths without their going into the hands of the joiner; and the key was forced through by a plunger working up and down, by a guide and parallel motion on the end of an iron beam. A similar plunger force them through the compressing box; and 1100 were completed in ten hours. A part of the power may also be applied to drill the stone blocks for the permanent way. The cost of the whole, with the necessary shops, amounted to about L.1500; but the keys may be made for L.8 per thousand, if a cheap pattern be adopted. The circular saws also cut up the waste wood into treenails, which were bored by a lathe adapted to that purpose, the whole being worked by steam. It is found to save the labour of fifteen men. When this sort of chair is used, it will occasion a great saving of time and trouble, if all the chairs are either made by one contractor, or every one gaged before it is received; for if there be the least difference in

the size, it requires a different set of cutters, and a different compresssing block for each sort, besides giving a great deal of trouble to the men employed in laying the way. The same remark applies to the rails. The best way is to take plenty of time, by beginning early. Find a respectable man, and let him have the whole job, at a sum varying with the price of iron.

In iron keys there are many more ways of shaping them. The accompanying drawing (fig. 13.) shews a very good one, where the rail has a web on one side of the bottom only, and the other side of the chair is notched to receive an iron pin. The only objection ever urged against iron pins is, that they are apt to get loose. This might be obviated by splitting the end which enters first, and opening it when driven home. If this be done, the other end should have a head, so that a clawed crowbar could be applied in order to draw it out.

Fig. 13.

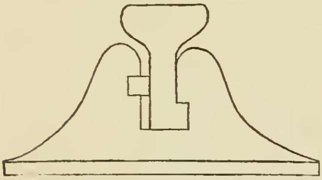
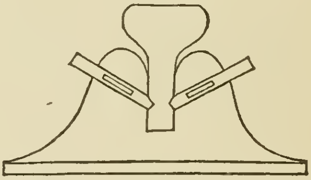


Fig. 14.



The annexed drawing (fig.14.) shews another good form, invented by Mr. Robert Stephenson, where the rail is confined by two bolts having angular ends, which enter a small score in the rail, and are keyed home by iron keys with split ends; the key hole in the chair, and that in the bolts, being so proportioned, that the effect of keying up is to press the end of the bolt against the rail. In these chairs there is a moveable piece of iron, the bottom of which is circular, and the top flat, laid in a properly-formed receptacle in the bottom of the chair; and on this the rails rest, so as to give perfect ease to any motion produced by flexure.

Mr. Buck's chairs (fig. 15.) are well spoken of. The wedge is driven against the rail by a vertical key. The

accompanying drawing (fig. 16.) shews another good form,

Fig. 15.

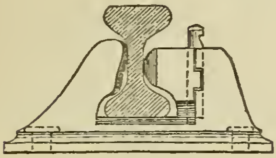
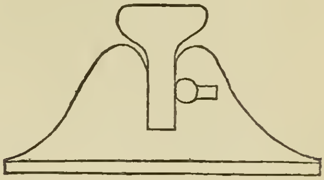


Fig. 16.



in which an iron ball takes against the rail, and is keyed close up to it by a longitudinal key. The joint chair is laid down, not at right angles with the rails, but diagonally, and is cast with a split end, rather smaller than the rail. It has therefore to be chipped to get the rail in.

There is however a great loss on all these chairs, through their being made of cast iron. This occasions numbers to be broken in fixing and keying. To prevent this, wrought iron chairs may be made, by rolling the iron into the required form in lengths, and then cutting up the lengths into chairs by shears; after which they may be drilled and completed.

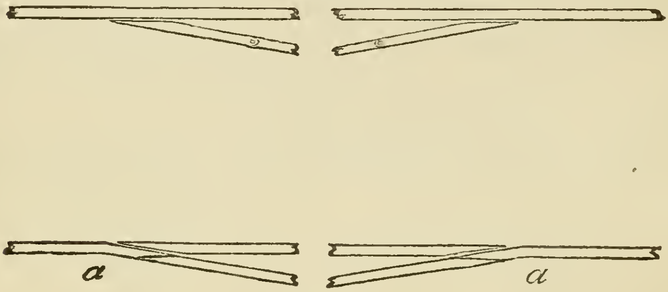
A chair upon a universal joint has been patented, so as to allow the rail to accommodate itself to the sinking of the block; but it has not been adopted on any railway that we are aware of. The inquiries necessary under these and other heads, as the works increase in their number and magnitude, will be best met by the directors dividing themselves into sub-committees under the various necessary branches, which is always advantageous, as long as there is one managing head to bring all the parts to bear upon a common focus.

Points and crossings are things which require considerable attention; and great care should be taken that they are laid down on a plan which combines simplicity with safety. Where one line intersects another, and the crossing is a fixture, or as it is called, a through-crossing, no more will be necessary than to bolt the sleepers well together, and pay rigid attention to the adjustment of the rails; but where it

is requisite to have the power of going either on one line or the other, as at a siding, the matter becomes more difficult, and the mode of doing so may be considered as far from settled, opinions being still very various.

The oldest form is the common switch, where, upon one side of the line of rails, is a bar, moveable on a hinge, capable of being laid into either the main line, or the line of sidings. (Fig. 17.) Abreast of this is a fixed check rail,

Fig. 17.



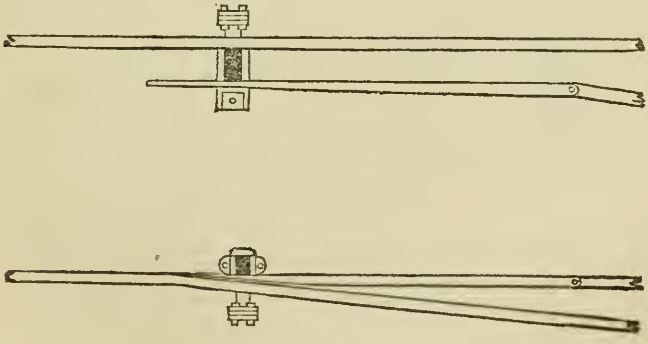
the main rail being bent, and having a nick in it (*a*) for allowing the flange to pass when the carriage is not to shift its line. The left hand half of the figure exhibits the same thing for the opposite line of rails. A check rail must also be placed at each point, so as to ensure the train going upon the required line when the switch is placed in the proper position. The switch is generally moved by a horizontal bar or rod of iron connected with it, which is drawn in and out the required distance by an eccentric, at the opposite end to that which is connected with the switch. This eccentric is attached to a vertical rod, coming up about three feet inside an iron standard, and it is turned at the top by means of a lever key which can be taken off at pleasure, and which no person should be allowed to touch except the switchman. This form, although the oldest, is a very good one, and is very easily understood and managed. There is, however, a very cheap and good

plan of moving them, instead of an eccentric. This is a vertical lever, which draws them backwards and forwards, the handle springing against an arc with notches to receive it in each position. This might be placed inside the switchman's sentry-box, where it could be locked up if he was unavoidably absent, and no one could touch it.

Another form, also much approved of, is what is called the check-rail, to distinguish it from the former, which is called the switch-rail. In the check-rail there is a moveable bar to both sides of the line of rails. These are moved simultaneously, by the eccentric being connected to each of them by a cross bolt. The action of the check-rail and the switch-rail has this difference, that it takes place on different sides of the flange, the check-rail acting on the outside of the flange, and the switch-rail on the inside. The check-rail is not so good as the switch, nor is it so easily understood. It is shewn with its eccentric in Plate CCCCXX. Fig. 1 is the slide rail in plan, fig. 2 the elevation, fig. 3 the elevation of the eccentric, fig. 4 the point, and fig. 5 the general arrangement.

Another form which has been much adopted, is Curtis's slide rail. This has a double bar upon each side of the line of rails, is moved by an eccentric like the others, and

Fig. 18.



is very effective, but expensive. In fact, they all an-

swer the purpose, but the slide rails require signals, which we shall hereafter describe. But this is not the case with the others. Opinion seems now coming back to the old switch rail, modified by making the switch part of it considerably longer, and having it kept in the right position for the main line, by a weight or spring, so that when the train is to go on the siding, the switchman has to hold the switch all the time the train is passing. This is objectionable. But the construction has an advantage which overbalances any thing which can be said against it ; namely, that it will be opened by the wheel of the engine, if purposely put wrong, so that the train can by no possibility get off the line of rails, unless it is actually wedged immoveably in the improper position. This is susceptible of further improvement. As it stands, it is the subject of a patent, but we question whether it could be sustained.

We have seen a very cheap, simple, and effective switch on the Great Western Railway, adapted for peculiar situations, where fixed crossings would be disadvantageous. This consists of a switch moveable at the middle by a pivot, instead of at the end. This connects two lines in either direction, but is not to transfer trains from one to the other. Whichever plan may be adopted, we should recommend one set to be made rigidly accurate, and then that templates should be formed from these as a guide for all the others. No method but this will ensure the correctness of the whole ; and crossings being always dangerous, they should never be used if it can be helped, except on a station.

This will not always be found practicable. For instance, in the early stage of a railway, it may often be necessary to cross from one line to the other, whilst some necessary repairs are going on. Railways consisting of a single line of rails, must have sidings laid down for the trains to pass each other ; and on double lines, it being so advantageous with reference to expense, that goods should be less rapidly conveyed than passengers, siding places should be constructed

for this purpose. The number and length of these would entirely be governed by the nature and extent of the traffic, and the plan on which the line is worked. They should never, for general purposes, be less than four hundred feet in length.

It will conduce to economy, if the necessary number of sidings can be determined, so that the land may be procured for them whilst the company have power to take it under their act; and where they take place on embankments, the necessary width should, whenever it is practicable, be constructed at the same time as the rest of the embankment; for by having to widen it afterwards, the part added never consolidates well with what has been some time done, but always settles at a different rate, and is apt to slip.

A considerable saving will be effected by having, at an early period, a constructing department. This should be begun as soon as possible, and kept on a small scale, which is much more advantageous than beginning it late, and having it on a large one; inasmuch as it is always ready to make waggons and barrows during the progress of the works, which will generally be found necessary, either from contractors not having enough, and the company being obliged to put on more, or from the works being given up, and the company being obliged to take to them, which, when time is an object, occasions an enormous outlay. We have known contracts let for L.100,000, which, when afterwards taken up by the company, have cost more than triple that amount. The only way to prevent this, is to have a special care that the contractor is from the first doing his periodical share of work; and if not, to put on hands and tools at once, and keep up the required allowance.

If this be not done, either the railway will not be opened at the time it ought to be, to the serious loss of the proprietors, or measures must be taken which will involve a heavy outlay. For instance, if time is to be fetched up in the earthwork, it can only be done by throwing part of the cutting

into spoil, and excavating it out of the middle instead of the ends, by means of barrows pulled up by horse-runs, and taking a corresponding quantity of earth from a side-cutting, to form the embankment, the expense of which is obvious.

In the construction department, may be made all the second and third-class carriages, horse boxes, carriage trucks, goods' waggons, earth waggons, barrows, and many minor matters which will be noticed in their proper place. The head of this department should draw upon the store-keeper for all his materials, keeping a regular account of his expenditure of them, and a debtor and creditor account of each carriage, both for making and repairs. The wheels and axles, springs and brass work, will be best furnished by contract from some respectable house.

The mails should be fitted up in conjunction with the post-office authorities. One sort of those now used are divided into two parts. The first is a sleeping-room, where two hammocks are hung up ; the other is an office fitted up with drawers and pigeon-holes, for the purpose of sorting the letters. Three men are employed, so that by night two are in bed, and one at work, who is in turn relieved by the others ; but the nature of this service will of course vary with the length of journey, and the quantity of the correspondence.

The ordinary kind of mails, (Plate CCCCXXI. fig. 1.), which only carry the guard and the bags, without affording the means of sorting the letters, are made narrower than the other carriages in the body, and are placed on a platform over the double framing. The centre coach carries four persons inside. The first coach is built as a coupee, carrying only two persons ; and the hinder part will carry either four persons sitting, or two lying down. The fares of course correspond with the accommodation. In the bed carriage it would be double, every person occupying the usual seats of two. The carriage is divided in two parts longitudinally, so that each person lying down has half the carriage to himself; but if

two persons take this half, their fare should be lowered in proportion.

The bed is made by placing a third cushion fixed to a board, which slides in between the two opposite seats, filling up the place where the legs of the passengers were. A door then lifts up at the back of the carriage, from the seat upwards, and fastens to the roof. This door opens into a boot which is fixed behind the mail, and into the opening go the feet of the person, the total length being about six feet four inches. A stuffed hair pillow is also provided; and we do not see why those who choose to pay for it, could not have yet more accommodation, namely, the luxury of undressing, and going really to bed, instead of laying down without taking off their clothes, the difference in comfort between the two being so very great. All that is necessary for this purpose is to have a box containing two blankets, a pair of sheets, pillow-case, and night-cap, which could be easily stowed in the boot, and when emptied and hung up to the roof, would form a receptacle for the passenger's clothes. There is nothing to prevent this in a practical point of view; and the advantage of such an arrangement, especially to persons in delicate health, would be so important, as to fully justify the trial. In fact, carriages could easily be constructed with bed places on each side, like the cribs in sailing packets, and would doubtless pay well.

The first-class coaches had better be made by contract with some respectable builder. (Plate CCCCXXI. figs. 2 and 3.) Each coach should consist of three bodies or compartments, the extreme length being 15 feet 6 inches, and the length of each body being 4 feet 11 inches. The breadth should be 6 feet, and the height from the floor to the roof, 4 feet $6\frac{1}{2}$ inches, all inside measure, and exclusive of the stuffing. The frame-work of the bodies should be made of well-seasoned ash, of the following dimensions: For the bottom sides, $2\frac{1}{2}$ inches by $4\frac{1}{2}$ inches; the standing pillars at the corners and door ways (twenty in the three bodies,) should be $2\frac{1}{2}$ inches,

with a sweep 3 inches in the widest part, and the turn under, $2\frac{1}{2}$ inches, the standing pillars in the door-ways being strengthened in the bottom by uprights of birch, firmly secured to the seat rail. The top rails should be $2\frac{1}{2}$ inches by $1\frac{1}{2}$ inches, and there should not be less than twelve of them at each end; the cross bars across the divisions (one for each,) $2\frac{1}{2}$ by 1 inch; the seat rails (ten in the three bodies,) $1\frac{1}{2}$ by $2\frac{1}{2}$ inches; the hoop-sticks to support the roof, (four in the two end bodies, and three in the middle body,) $2\frac{1}{4}$th in width by $1\frac{5}{8}$th in thickness. The sides should be battened with ash of the same strength, and in the same manner as the ends of the coach.

The flooring should be of American pine $1\frac{1}{4}$ thick, plated underneath with three straps of wrought iron $1\frac{1}{2}$ inches in width, by 1-4th of an inch in thickness from end to end, secured by about 100 clip-headed bolts and nuts. The divisions between the bodies, the seat boards, and the roof, should each be of American pine 3-4ths of an inch in thickness; the roof should be covered with three hides, weighing not less than 38 lbs. each, protected on the top with ribs of ash screwed on, 3 inches apart, $2\frac{1}{4}$ inches in breadth by 5-8ths in thickness; it should be bounded by a beading of ash, $1\frac{1}{2}$ inches square, screwed on, and projecting so as to allow the rain to drop clear of the pannels; it should also be channelled, and stand something higher over the roof upon the outside, and be painted white. Seats must be provided at both ends of the roof, to hold two persons each, with iron seat-rails, three steps on each side, and two iron handles at each end, covered with leather, to mount by, and a foot-board of birch, supported underneath by iron stays. The roof, for the space of 8 feet 6 inches, should be fenced along and across with luggage rails of iron, 5-8ths of an inch in diameter, supported, at intervals, with uprights $4\frac{1}{2}$ inches high, and an oiled canvass luggage sheet with straps, of sufficient dimensions to extend over the whole.

The entire exterior of the coach should be pannelled with

well-seasoned pannel board, the upper quarters half an inch, the lower quarters 5-16ths, and the ends half an inch thick; the pannels, before being fixed, should be covered with canvass glued on, and when fixed, which ought to be done with copper sprigs one inch apart, they should have another canvass covering glued upon them. The mouldings are made of brass, as also the door and side handles; and there should be four lamp-irons to each coach, two at each end.

The windows should be of good plate glass, $22\frac{1}{2}$ inches by 19 inches, and not less than 5-16ths thick, and the frames should be made of well-seasoned oak, $1\frac{1}{2}$ inches in breadth, and covered with strong black velvet, or painted, filled up, pumiced and varnished as may be required. Small leather pads should be put at the bottom of the glass stop for the glass to fall upon when let down; and side lights may be added if required.

The painting ought to consist of three coats of white lead or colour, and four coats of filling up; after being well pumiced, the body should receive three coats more of the same colour, and then be finished with two coats of a colour to be approved of by the directors. The upper quarters should be painted black in the same manner, and the whole body varnished with four coats of the best varnish, the pannels being lettered in gold, and ornamented with a device to be approved of by the directors.

The inside should be lined throughout with cloth of a quality worth, at the present time (1839), 12s. 6d. per yard, and 60 inches in width, the quantity required for the three bodies, being about 38 yards; lace, (7 dozen for the three bodies,) 18s. per dozen; seaming do., (12 dozen) 3s. 6d. per dozen; pasting do., (4 dozen) 3s. 6d. per dozen. The holders and glass stirrups should be of lace lined with strong leather hat strings.

The floor should be covered with the best Brussels carpet; the back and cushions stuffed with the best curled horse-hair, the quantity required for the three bodies being

about 112 lbs.; and the seats divided with four arms in each body, fixed on with iron cover plates and screws and finished with broad mahogany tops lined and stuffed with horse-hair. Each seat should also be numbered with a japan label and gilt figures. The bodies should be firmly fixed upon the under carriage with strong bolts secured by means of nuts; and the whole of the work should be of the strongest and most substantial nature, all the iron work being of the best quality. The weight of that portion attached to the bodies, consisting of luggage rails, steps, foot-board stays, &c., is about 1 cwt. 1 qr. 24 lbs.; and screws should be used throughout instead of nails.

The extreme length of the under carriage frame ought to be 15 feet 8 inches, the buffers extending 1 foot 9 inches beyond at each end, and the whole should be made of well-seasoned ash, of the following dimensions: The carriage sides, two on each side, may be made in two pieces, if it be thought proper, spliced in the middle, and fitted with iron bolts and nuts; they should be 3 inches square, coupled together vertically by wrought iron props and cover plates, 8 of the former in each carriage, weighing 2 qrs. 25 lbs., and 4 of the latter, weighing 2 qrs. 18 lbs. The ends of the carriage should consist of two pieces of ash, extending from side to side (6 feet 1 inch) $3\frac{1}{2}$ inches in width by 3 in thickness, and swelling to $11\frac{1}{2}$ inches at the deepest part, being morticed together as in the sides, only with three upright blocks of ash instead of iron.

The frame should be strengthened by four diagonal, two centre longitudinal, and two centre cross stays of ash, each 3 inches by $2\frac{1}{2}$, extending to the lower carriage side, morticed into a solid piece of ash in the middle of the frame, 2 feet 3 inches by 1 foot 4 inches, and 3 inches in thickness, and secured to it, as well as the carriage sides, by strong angle plates of wrought iron, and plated at the corners, the plates being 3-8ths in thickness and $2\frac{1}{2}$ inches in width, of wrought iron, fixed on with half-inch bolts and nuts. The two centre

stays, both cross and longitudinal, and the whole lower carriage sides should be plated throughout, on one side, with wrought iron 3-8ths in thickness and $2\frac{3}{4}$ inches in width, fixed in the same manner as the cover plates, with bolts and nuts. The weight of the plating will be about 2 cwt. 0 qrs. 20 lbs., and that of the bolts and nuts (about 350 of each) 1 cwt. 2 qrs.

There should be axle-guards of wrought iron, tapering from 3-4ths to 5-8ths of an inch in thickness, firmly fixed to the carriage sides by bolts and nuts, in exact square with each other, at the distance of 8 feet 6 inches from centre to centre. The steps, consisting of 18, and weighing about 1 cwt. 2 qrs. 22 lbs., having a tread of 12 inches by 9 inches, should be fitted in the same manner to the carriage sides. There should be 8 wrought iron roller boxes, weighing, with the rollers, 3-4ths of a cwt.; and these should be screwed upon the under part of the carriage sides, for the extremities of the side, or bearing springs, to rest and work upon.

To each carriage there should be four large buffer rods, of wrought iron, weighing 2 cwt. 1 qr. 6 lbs., with a butend of ash 14 inches in diameter, covered with stout leather, and stuffed with horse-hair. These rods should abut upon two large springs, having fifteen plates each, of 1-4th inch of steel, 3 inches in breadth, and, when fixed, 5 feet 9 inches in length. There should also be two drawing springs, with six plates each of steel, of the same dimensions with the buffer springs, and 3 feet in length; so that the weight of the four springs would be about 3 cwt. 0 qrs. 25 lbs. These should be fitted into a groove, which should be firmly bolted upon the slab of ash in the centre of the frame, with liberty to work to and fro for the space of $2\frac{1}{2}$ inches. The buffer and draw-bar apparatus is shewn in Plate CCCCXXII. fig. 2.

The iron work connected with the buffer and drawing apparatus, besides the buffer rods already mentioned, consists of the draw rods and plates attached, weighing about 3 qrs. 22 lbs.; four square socket rings and buffer plates,

weighing about 2 qrs. 18 lbs.; one groove plate, two side plates, and two edge plates, weighing together about 2 qrs. 6 lbs.; and the weight of sundry pieces of small iron-work about the frame, which may be estimated at 3-4ths of a cwt.

The whole of the steel for the buffer and draw springs, as well as that for the bearing springs, should be well tempered and of the best quality; and all the iron work should be of the best description, well and neatly wrought, filed, and fitted. The framing should be substantial, and constructed on the most approved method adopted in the recently-built railway carriages. The carriage should be painted with five coats of paint of a colour corresponding to the bodies, then neatly picked out, and finished with two coats of the best varnish. There should be three chains at each end of the carriage 18 inches long, with an open link, and bolt and nut at one end, and a strong hook at the other. The centre chain being the one by which the carriage is sometimes drawn, should be rather stonger than the other two, which are only required for additional safety; the weight of the six should be about 1 cwt. 2 qrs. Coupling bars are, however, preferred to draw-chains, and should supersede them entirely.

As it is not necessary that every carriage should have a break, this should form the subject of a separate tender. It consists of a number of levers, tooth and pinion wheels, &c., the application of which can only be well understood by inspection. The weight of the whole apparatus is about 4 cwt.

The wheels should be made, with the rim and spokes, of wrought iron, and the nave of cast iron. The outer rim or tire, should be tapped on the inner rim, with not less than eight screw bolts and nuts in each wheel; besides being in the first instance shrunk on the axle, which should be made of the best rolled or wrought iron, 3 inches in diameter in the centre, and $3\frac{1}{2}$ where it passes through the nave; and it should be turned down to $2\frac{5}{8}$ inches, for an outside bearing of $4\frac{1}{2}$ inches in length, which should be case-

hardened. The wheels should be firmly keyed on the axle with a 5-8th inch key, according to a guage; and the tire should be turned to a template, which, with the guage, ought to be furnished to the maker. The whole should be painted, and picked out, with one coat of paint and one coat of varnish.

The weight of the four wheels and axles should be about 18 cwt. The axle-boxes, which should be of cast iron, should be fitted up with brass steps to suit the journals. On the axle-boxes should be fixed the side or bearing springs, four in number, having each twelve plates of 1-4th inch steel, 3 inches in width; and when they are weighted they should be 5 feet in length, so that the weight of the four will be about 3 cwt. 1 qr. 14 lbs., and the total weight of the iron work for each carriage about 47 cwt.

Wheels for engines and carriages were at one time made of cast iron, but the wear was found to be enormous. They were afterwards case-hardened by being cast inside a large circular rim of iron, against which the outer circumference of the wheel came into contact, and the rapid cooling which this gave the wheel on its wearing surface, caused it to become so hard, that it would last for many years. The adhesion of these wheels, however, is less than that of wrought iron. The speed now attained on railways, and which will be expected by the public to increase, renders the use of cast wheels unsafe; and the kind now generally employed have wrought iron tires and cast iron spokes. The relative wear of cast iron tires compared with wrought, is for the former, about 0·67 of an inch per annum, and for the latter 0·125, or in the ratio of 5 to 1 in favour of the wrought. Mr. Stephenson's engine wheels have cast iron rims, wrought iron hollow spokes, cast iron naves and wrought iron tires. The spokes are laid in the mould and the rim cast on to them, brass being used to get a secure joint. Three-quarters of an hour is allowed for cooling, and then the nave is cast, thus allowing contraction to take place. The rims and tires

are both turned, and the rims put on hot and bolted on with fresh bolts; the driving wheels have no flanges, and are a little coned to suit an inclined rail; the tires squeeze out as they wear, and are replaced by new ones when required.

Fig. 19. is Mr. George Stephenson's patent wheels, the nave and inner rim of which are of cast iron. The spokes, which are hollow, are made of wrought iron; and these being laid in the mould, the nave and rim are cast to them, borax being used to gain a more perfect hold between the two metals. The rim is afterwards turned in a lathe by a very slow motion, which takes off the iron to give it the true cylindrical form. A wrought iron tire with a flange, which is formed by rolling, is then placed around the rim, and secured on it in the usual manner.

Fig. 19.

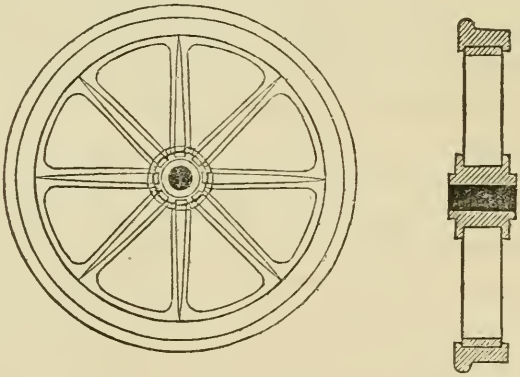
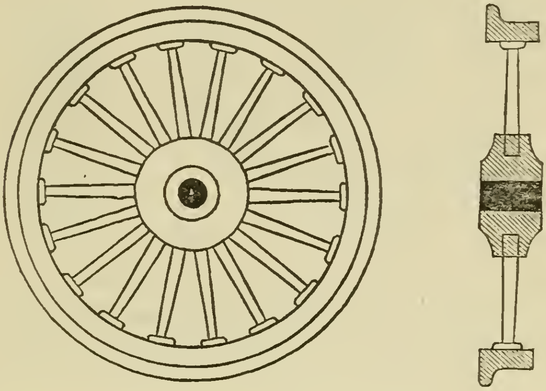


Fig. 20 is the wheel patented by Mr. Losh. The spokes, rim, and tire of this wheel are all of wrought iron. The spokes are made out of boiler plate, and bent so as to form the rim as well as the spoke; and the two ends of each coming into the centre, and having been previously heated, the nave is cast round them. Wrought iron hoops are sometimes shrunk on to each side of the nave to guard against its splitting. The tin is rolled with a bead inside,

which takes against the inner rim and prevents its coming off; and it is put on by being heated red hot, its contraction in cooling giving it a firm hold on the inner rim. The slight bend given to the spokes, which is done to induce elasticity, was not in the original specification of the patent.

Fig. 20.

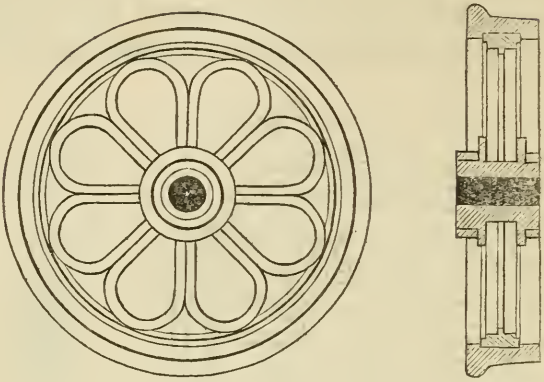


Mr. Hague made a very similar wheel to this, and an action was entered against him by Mr. Losh, for an infringement of his patent; the jury, however, found for the defendant. Mr. Hague's wheels are made exactly in the same way as Mr. Losh's, except that the ends of the iron, which is bent round to form the inner rim and spokes, are welded together before the nave is cast round them. Losh's wheels have always performed well, and have been extensively used on railways, but they have broken in several cases.

The above are two of the most general forms of carriage wheels; but those lately made by Mr. Joseph Bramah, at the Grosvenor Works, Pimlico, London, (fig. 21.) have hitherto surpassed all others, and we do not see why they should not equally answer for engines, as they admit of any required strength, and may be modified so as to be well adapted for locomotives. They are made in the following manner: The looped spokes are in the first instance rolled out to the required sectional figure in straight pieces; these

are heated red hot, and one end being wedged against an

Fig. 21.



iron former, the workman takes hold of the other with his tongs and bends the straight piece round the former, which thus gives the spoke the looped appearance seen in the figure.

The requisite number of these spokes are then placed in the proper position, with their circular ends inside an iron gauge ring, and the nave is cast, which in this process embraces all the opposite or central ends of the spokes, by which they become fixed into it with perfect solidity. The wrought iron inner tire is then made hot and contracted on to the spokes; and it is retained by a rabbit on their circular ends. The outer tire, after being rolled to the sectional figure, is heated and bent round a former, in the same manner as the spokes were, and it is then welded into a circle and put on the outer tire hot, so as by its contraction to have the firmest possible hold, which is also aided by bolting the two together. The outer tire and the working part of the axle is then accurately turned to the required shape; and these combined operations produce a wheel which, whether looked at as to the scientific principles of its construction, or to the practical results of the trials hitherto made with it, has been completely successful.

There is still a difference of opinion amongst engineers whether the rail should be inclined or not. The gain and loss may be thus stated. The advantages consist principally in preventing so much wear both on the tire of the wheel and the rail, but chiefly the former, for when the rail is upright, the wheel, theoretically speaking, is only in contact with it on a line having hardly any breadth This is found to wear away the wheel very fast, and the rail likewise suffers a loss on the side where the contact takes place; besides which, the wear approximates the tire of the wheel more and more to the shape of a cylinder instead of a cone; and the rail also partially adapts itself to this action, in each case, through the abrasion of the working lines. In addition to the increase in repairs, through these causes, the wear is to a certain extent unequal, and an irregularity is produced which consequently leads to an unsatisfactory performance between the engine and the rails. But this is avoided by inclining the rail so that it receives the wheel on nearly the whole of its bearing surface; and 3-8ths of an inch in 11 inches is the inclination of the blocks on the London and Birmingham railway.

The disadvantage consists mainly in this, that if the wheels do bear on the whole of the surface, say two inches, there must be a constant rubbing action going on, arising from the unequal velocities with which the outer and inner tire of coned wheels revolve, and this will of course be equivalent to dragging the whole train for a certain distance with every one of the wheels locked. Let us see what this dragging will amount to.

Let d be the greater diameter of the coned wheel, and d' its lesser, each in inches; taking the bearing surface at two inches, and supposing that in this breadth the two diameters differ half an inch, both which suppositions are in excess, we then have

$$\frac{d—d'}{2} \cdot 3{,}141593, \text{ or } (d—d') \cdot 1{,}570796$$

for the rubbing at a mean in each revolution of the wheel, and the length of this revolution will be

$$\frac{d+d'}{2}.\ 3{,}141593,\ \text{or}\ (d+d').\ 1{,}570796.$$

If we take $d = 60\frac{1}{4}$ inches, and $d' = 59\frac{3}{4}$ inches we get $(d - d')\ .\ 1{\cdot}570796 = {,}5\ .\ 1{\cdot}570796 = {\cdot}785398$ inches, which is the quantity of dragging for each revolution, the length of which will be $(d+d').\ 1{\cdot}570796 = 120\ .\ 1{\cdot}570796$ $= 188{\cdot}49552$ inches, we then have this proportion,

Yards.	Inches.	Yards.	Inches.
5,235986 :	785398 =	1760 . :	264

Hence, the dragging of the whole train will be 264 inches per mile, or 733 yards in 100 miles for each wheel. This, at first sight, appears considerable, but in practice it will be much less. The data have been taken large to shew the limit of this action, and the whole bearing surface is not practically in contact with the tire of the wheel, arising from the various imperfections inseparable from the manufacture of both wheels and rails, particularly the latter, although it must be allowed that the better they are made, the more dragging will take place; and likewise the more the surfaces come into contact, the greater will be the effect of shocks from bad joints and other imperfections. Still our opinion tends to inclining the rail.

It appears absolutely necessary in railroad engines and carriages, that the wheels should be keyed to the axles, the wheel and axles both turning round together; several attempts have been tried to introduce fixed axles, but although the greatest care has been taken in the manufacture, both in boring the hole in the nave, and turning the axle, yet a lateral shaking has always been found to take place, throwing the carriages off the rail on very moderate curves.

The quantity of inclination which the cone of the wheels should have, will, strictly speaking, depend on the radius of the curve. But, as half an inch on $3\frac{1}{2}$ in width, or 1-7th of

the width is found to be practically advantageous, in keeping the flanges of the wheels from rubbing against the rails in straight lines ; and, as by raising the outer rail, the effect of gravity may at any given velocity be made to neutralize the centrifugal force, that inclination of the tire of the wheel may be adopted, except in very extraordinary cases. With this slope, and a wheel of three feet in diameter running on a line of rails 4 feet $8\frac{1}{2}$ inches in width, with a play of one inch, Mr. Pambour gives the following table of the elevation necessary in the outside rail:

Radius of the curve in feet.	Surplus elevation of the outside rail.		
	At 10 miles an hour.	At 20 miles an hour.	At 30 miles an hour.
	Inches.	Inches.	Inches.
250	1·14	5·60	12·99
500	0·57	2·83	6·56
1000	0·29	1·43	3·30
2000	0·15	0·71	1·65
3000	0·10	0·47	1·10
4000	0·07	0·36	0·83
5000	0·06	0·28	0·66

To enable this calculation to be made for any other inclination, or suitable curves to be made where the inclination is determined, we shall explain the method of investigating the subject.

The resistance on curves is of two kinds, one from the carriage having to turn on the rail without any corresponding play on the axle, thus producing a dragging of the wheel, which takes place on that which is going over the inner part of the curve; and, secondly, that which arises from the centrifugal force, and which causes a friction to take place between the flange of the wheel and the rail. To correct these, the inclination of the coned wheel, the radius of the curve, the velocity and the elevation of one side of the line of rails, must have definite relations, and the wheels must have sufficient play between the two rails to admit the

centrifugal force without being able to induce the second resistance, yet under given conditions to correct the first.

To arrive at this result, whilst the outside wheel of the carriage describes the arc mm', (fig. 22.) the inside one must describe the arc nn' terminating at the same radius; the working circumference of the wheels must therefore be represented by these arcs, and putting

D=diameter of the outside wheel,

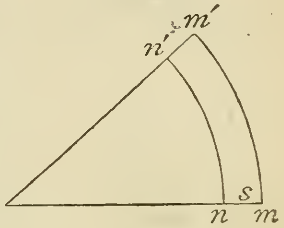
D′=diameter of the inside wheel,

π=the ratio of the circumference to the diameter,

we have $mm'=\pi D$

$nn'=\pi D'$,

Fig. 22.



Also, as the two arcs are terminated by the same radii, we have

$$\frac{mm'}{nn'}=\frac{mo}{no},$$

and if we put the radius of curvature $(os)=r$ and the half breadth of the road $=e$, the above proportion will become

$$\frac{mm'}{nn'}=\frac{r+e}{r-e},$$

or

$$\frac{D}{D'}=\frac{r+e}{r-e},$$

and

$$D-D'=D\left(1-\frac{r-e}{r+e}\right)=\frac{2eD}{r+e},$$

which gives the difference necessary in the diameters of the wheels, in order to produce the required effect; and in order to know what lateral play must be had, if we take the inclination of the tire at $\frac{1}{a}$, we find this to be

$$\tfrac{1}{4}\,a\,(D-D')$$

and substituting for D—D′, its value found above, we have the lateral motion equal to

$$\frac{aeD}{2(r+e)}.$$

We have now to obtain the necessary displacement by means of the centrifugal force, and for this purpose putting
r=radius of curvature,
V=velocity,
m=mass of the moving body,
$g=32\frac{1}{6}$, or the accelerating force of gravitation in 1 second,
f=the centrifugal force produced on the curve,

we have $f=m\dfrac{V^2}{r}$,

but P=the weight of the same body, we have

$$P=gm,$$

or $$m=\frac{P}{g},$$

and $$f=\frac{PV^2}{gr};$$

making a foot in each case for the unit of space, and a second for the unit of time, we get the measure of the centrifugal force represented by its proportion to the weight P. Thus on a curve of 500 feet radius, at a velocity of 20 miles an hour, or 29·25 feet per second, we have

$$f=P.\ \frac{\overline{29{\cdot}25)}^2}{32\frac{1}{6}\,.\,500}.$$

or about $\frac{1}{19}$. P, the effect of which force in the direction of the radius, will of course be to press the carriages against the outside rail till the flange of the wheel stops them ; and the elevation of the outer rail must be such that the centrifugal force is so balanced by the natural tendency from gravitation, by which the carriages would slide towards the inner rail, that the coned wheel corrects the effect of curvature without producing a friction on the flange,

calling y=the elevation of the outside rail,
$2e$=the breadth of the way,

the inclination of the plane on which the carriage wheels are placed, will be

$$\frac{y}{2e},$$

and the gravity of a body weighing P, will be

$$\frac{Py}{2e},$$

and this force tending to bring the carriages towards the inner rail while the centrifugal force $\left(\frac{PV^2}{gr}\right)$ occasion them to approach the outer one, the height y of the outer rail above the inner one, if we wish the carriages to run in the middle of the rails, must evidently be taken, so that

$$\frac{Py}{2e}=\frac{Pv^2}{gr},$$

in which case we have an equilibrium between the two forces. But we require a tendency outwards to correct for the curvature, putting this$=\mu$, we get

$$\mu=\frac{aeD}{2(r+e)}.$$

If we suppose this lateral displacement to have taken place, the inclination of the plane on which the carriages will be, is

$$\frac{y}{2e-\mu},$$

whilst, at the same time, from the coned form of the wheels, the tire having an inclination $\frac{1}{a}$, this lateral deviation to the extent μ, has produced a difference of height in both wheels amounting to $\pm\frac{\mu}{a}$, that is to say, the outer wheel will be raised $\frac{\mu}{a}$, and the inner wheel lowered $\frac{\mu}{a}$, and the result or total inclination $\frac{2\mu}{a}$ will have to be added to that which has been produced by the difference between the height of the rails, hence, the outer wheel will be raised

$$y+\frac{2\mu}{a};$$

and as the base between the bearing points is $2e - \mu$, the carriage will be on a plane equal to

$$\frac{y + \frac{2\mu}{a}}{2e - \mu}$$

consequently to establish the equilibrium between gravitation and the centrifugal force required in practice, we must have

$$\text{P} . \frac{y + \frac{2\mu}{a}}{2e - \mu} = \frac{\text{PV}^2}{gr},$$

$$\text{whence } y = \frac{2\text{V}^2 ea + \text{V}^2 a\mu - 2\mu gr}{agr}$$

$$= \frac{2\text{V}^2 e}{gr} + \frac{\text{V}^2 \mu}{gr} - \frac{2\mu}{a}$$

$$= \frac{e\text{V}^2}{gr} . \left(2 - \frac{a\text{D}}{2(r+e)}\right) - \frac{e\text{D}}{r+e},$$

by which formula the table of surplus elevation for the outer rail has been computed, and of course the value of the radius of curvature, or any other element may be found, the others being given. As an example of the calculation, let us take the inclination of the wheel, or $\frac{1}{a} = \frac{1}{7}$; the velocity $= 29{\cdot}25$ feet per second; the breadth of the way $=$ 4 feet $8\frac{1}{2}$ inches, or $e = 2{\cdot}3542$ feet, D $= 3$ feet, when properly situated on the rail, and $r = 500'$ feet, we then have with $g = \frac{193}{6}$,

$$y = \frac{2{\cdot}3542 . \overline{29{\cdot}25)}^2}{\frac{193}{6} \cdot 500} . \left(2 - \frac{7 . 3}{2(500 + 2{\cdot}3542)}\right) - \frac{2{\cdot}3542 . 3}{500 + 2{\cdot}3542}$$

$$= \frac{2{\cdot}3542 . 855{\cdot}5625}{\frac{96500}{6}} . \left(2 - \frac{21}{1004{\cdot}7084}\right) - \frac{7{\cdot}0626}{502{\cdot}3542}$$

$$=\frac{2\cdot3542\,.\,855\cdot5625\,.\,6}{96500}\ (2-\cdot0209006)-\cdot014059$$
$$=\frac{2\cdot3542\,.\,5133\cdot375}{96500}.\ 1\cdot9790994-\cdot014059$$
$$=\frac{12084\cdot991425}{96500}.\ 1\cdot9790994-\cdot014059$$
$$=0\cdot125233.\ 1\cdot9790994-\cdot014059$$
$$=0\cdot247848-\cdot014059$$
$=0\cdot233789$ feet, or 2·8 inches.

We have here supposed $a=7$, or the inclination of the tire of the wheel to $=\frac{1}{7}$; but it is evident this must be such, that no rubbing of the flange will be produced on any curve on the line. We obtain this from the equation

$$\mu=\frac{ae\mathrm{D}}{2(r-e)}.$$

We first establish the play between the rails. Allow this to be two inches, or that the flanges of the wheels in their regular position are 1 inch from the rails; then μ must never be quite equal to 1 inch, and if we give to r in the last equation above, its numerical value for the worst curve on the line, and to μ its limit, a small quantity less than half the play of the wheels, we obtain the value of a, which we must use on that line, as follows:

$$a=\frac{2\mu(r+e)}{e\mathrm{D}}.$$

For instance, with half the play $=1$ inch, or ·0833 feet and $\mu=0\cdot9$ inches, or, 075 feet, we have $a=\frac{75\cdot3525}{7\cdot0626}=10\cdot669$ or the inclination of the cone $=\frac{1}{10\cdot67}$ of a foot; observing that if we have only one or two bad curves, we must examine whether we may not admit a little rubbing on them for a corresponding gain on the good ones. This investigation will shew how necessary it is that the play of the axles

on the carriages should be as small as can possibly be, or the effect of the coned wheels will be completely deranged. This is a matter which is much too little attended to in practi e.

When three classes of coaches are used besides the mail, the second class (Plate CCCCXXII. fig. 1.) should be fitted, as to wheels, axles, buffers, and iron-work, exactly the same as the first. The length of the coach is a little decreased, it has no lining, but should have air cushions; the three bodies are open to each other at the top and inside the carriage, and it receives fewer coats of paint and varnish.

The third class (Plate CCCCXXII.) should be entirely open, the wheels, axles, and springs being equal to the best, as conducing to the good order of the road; but there should be no buffer apparatus, only a draw-bar and spring, as shewn in Plate CCCCXXII. fig. 4. Buffer-blocks are fixed to the ends of the carriage, having an end-covering of leather stuffed with horse hair; every thing throughout each class should invariably be made to one guage, and all the nuts and screws to one tap, so that they will fit any coach indiscriminately.

If, however, it be considered preferable, with respect to classes of carriages, to have only two, the second class should have both ends built up the requisite height, and a roof put on, which may be supported at each division of the body, the sides being open, or, what is perhaps still better, the sides may be made to close at night, or in bad weather, at a slight advance in the fare. It will conduce much to the safety of those who may chuse to ride on the roof of the carriage, if a netting is always hooked between each carriage, just under the foot-board; at present, as the buffers are generally constructed, there is a distance of some feet between the ends of each carriage in the train, and on any obstacle causing a concussion, those sitting with their faces towards the obstacle, would be thrown under the wheels; a netting would entirely prevent this.

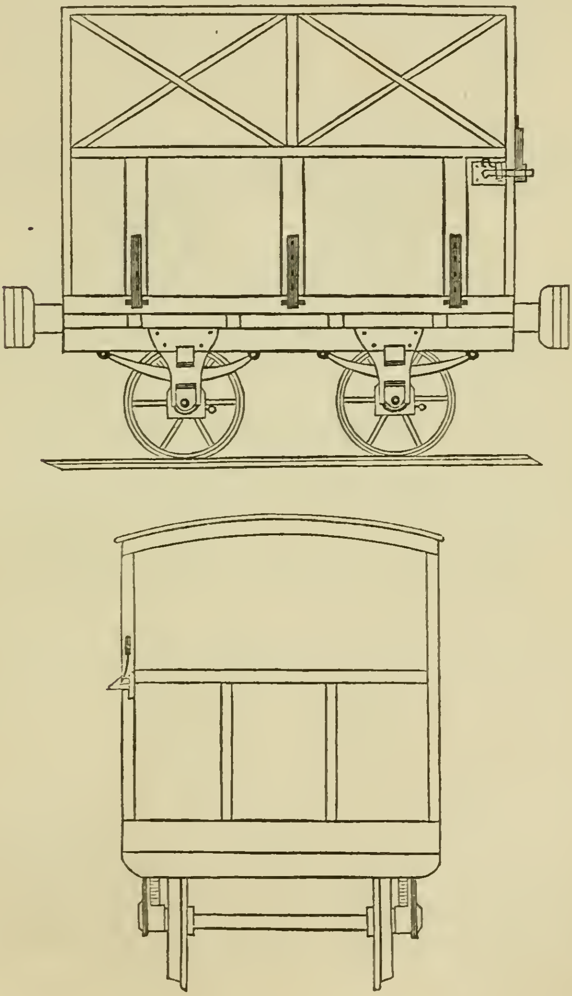
On the subject of buffing apparatus, a great deal of diversity of opinion exists, and a good deal of discussion has taken place, principally as to the merits of that which is in use on the Liverpool and Manchester railway, and a different sort which is employed on the Dublin and Kingston railway. (Plate CCCCXXII. fig. 5.), the latter being the invention of Mr. Bergen. As drawings are given of botht hese buffers, their difference will easily be seen ; but as yet opinion seems to incline to that used on the Liverpool and Manchester railway.

Their respective merits have been very strictly scrutinized by numbers of scientific gentlemen connected with railways ; but the question has not been satisfactorily set at rest. It will be seen that there is a totally different action induced upon the train in the two cases. In the Liverpool and Manchester railway, there is in fact a spring between each carriage, in consequence of which, on the train running against any obstacle, or if an engine should run against the train, the first coach would receive a heavy blow, the second a less heavy one, the third still less, and so on, each coach receiving a shock with a less velocity ; but the momentum would be the same minus a small quantity of friction, because the weight is increased at each shock, although the velocity is diminished. In the Dublin and Kingston, on the other hand, the springs are connected together from one end of the train to the other, hence, on this plan, each coach is struck by the same blow, and experience alone must decide upon their relative merits and demerits. The Dublin ones have this advantage, that the buffers are always the same height, whatever may be the load in the carriage, which is not the case in the other.

The horse-boxes are partially divided so as each to contain two horses, air-holes being bored in the front and back at the upper part. The upper half of each side should be hinged at the top, and the lower half at the bottom, to let down on the platform, and to the top half should be attach-

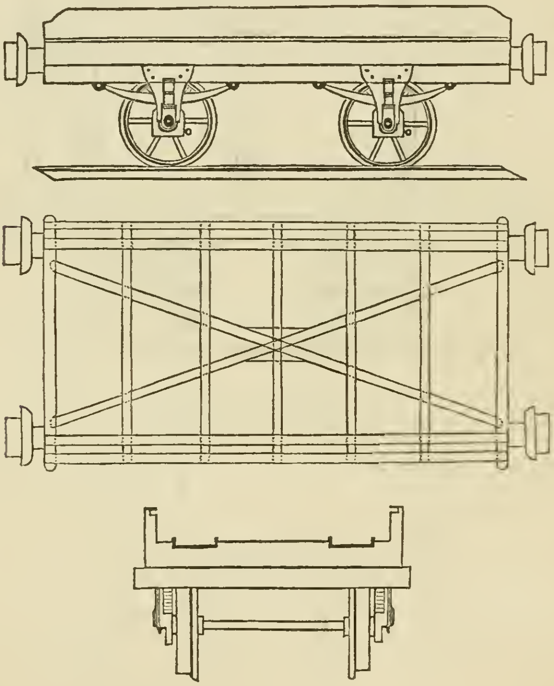
ed a circular catch of iron, which draws out when the side half is lifted up, and when it is at the requisite height, falls into a notch made to receive it, in which position it supports the side. An excellent latch for the lower half is shewn in the drawing.

Fig. 23.



Trucks for conveying private carriages should be made with reference to the height of the place where they will be embarked; they need be only a flat platform, [with short sides rising about 10 inches, on which two cross bars fix with pins through to the side, one being brought close to the fore-wheels of the carriage, and the other close to the hind wheels. Two iron clamps should be fixed in the bottom to clamp over the private carriage wheels, with a forelock

Fig. 24.



to secure them; and hand-hoes should be provided to clear these from the mud of the carriage wheels. The average weight of these different vehicles will be generally as follows:—

	Tons.	Cwt.	Qrs.
Goods waggons	2	0	0
Carriage truck	2	3	3
Horse box	2	10	2
Third-class carriage	2	11	0
Second class	3	3	0
First class	3	16	2
Mail, common	3	12	0
Mail for sorting letters		various	
Excursion carriage	3	2	3

This latter is used on some railways; it is an open carriage like the usual second-class, but fitted up internally as commodiously as the first class.

Earth waggons, two descriptions of which are given (Plate CCCCXXIII. figs. 1, 2, 3, 4,) need have no springs whilst the works are in progress; but those used after the railway is opened ought by no means to be without them, or they would considerably increase the expense of maintaining the road in good order. Goods waggons are best made with low sides, to which open-worked railing can be attached, so as to convert them into cattle-waggons, or to enable them to carry light bulky articles; closed sides and tops may also be used to them, with locks, if necessary. The nature of the presumed traffic will best determine both the form and size of these waggons. The elevation and end-view (Plate CCCCXXIII.) will require their iron-work as follows:—

Carts about six feet square and one foot in height, with the sides to let down, and a pole and handle in the front, the whole mounted on low wheels, will be found very convenient, particularly in carrying about blocks and ballast, one man being able both to draw them along and get them off the railway if required. All lines, when first opened, will require constant additions to be made to the ballast as the embankments subside, and these carts will be found to

afford the readiest means of tranferring it from the places to which it has been brought by the ballast waggons.

There is nothing in a railway which demands such serious attention as the stations, both as to their numbers, position, and the mode of constructing them. The number and situation will of course be mainly determined by the nature and extent of the surrounding population; and the first step should be to get a good map of all the places within the sphere of the railway, and to mark upon it the population of each place from the last parliamentary census; bearing in mind, that taking, for the present, railway-travelling to be twice as fast at half the cost of coach travelling, that a very wide portion of country will receive the benefit of a long line. We have explained this before; but that it may be perfectly understood, we shall shortly advert to it in a different shape.

For instance, suppose a line 100 miles long, and a person 50 miles at right angles to one end of it, who wants to go to the other end. If he travelled in a stage-coach along the hypothenuse of the triangle, he would go about 112 miles, say at 4d. per mile, his total cost would be L.1, 17s. 4d., and his time expended about 11¼ hours. On the contrary, if he came first to the terminus of the railway nearest him, and then went along the railway to the other terminus, he would have first 50 miles in a stage-coach at 4d., or 16s. 8d., with an expenditure of time equal to 5 hours, and then 100 miles by the railway at 2d., or 16s. 8d. more in 5 hours, the total time being 10 hours, and the total expense L.1, 13s. 4d., consequently he would save 4s. in money, and 1¼ hours in time, by taking the longest road.

There is no doubt but that the greater the number of stations, the more the travelling will increase; for it has always been hitherto found that the quick and cheap transit by a railway has not only increased the already existing traffic, but has actually created it where no traces could be found of it before. The nature of the produce, and the state of trade should also be taken into account in

determining both the number and the situation of the stations.

The minor stations along the line may be divided into two classes. The first might consist of merely one room, serving for office and waiting-room, where nothing but passengers and small parcels are sent either up or down. Such stations would do for small villages or points where only a limited traffic is expected. We do not, however, recommend these, although they are used on several railways. All passengers pay alike, and they are therefore entitled to the same accommodation. The other class should be a house containing an office, waiting-room in common, or which is better, one for each class of passengers, ladies' waiting-room, and two rooms for the inspector of police to reside in, a small office for the police, and a porter's room. To this would have to be added, if water was required to be pumped, a steam-engine, and the requisite room for the engineer, a locomotive engine-house when necessary, and a covered space for holding spare carriages, trucks, horse-boxes, &c., together with the requisite sheds, and an office for the goods department.

The entrance to the station should be protected from the weather, so that when carriages drive up, the passengers can alight under shelter, and there should be a platform next the railway, about the same height as the carriage floors, so that the passengers can walk into the railway-carriages without having to climb up the steps. Arrangements should be made, for the passengers who are going into the carriages to go all in upon one side, and those going out should get out from the other side; for which purpose the entrance should be on one side of the railway, and the exit on the other side. A light roof should be thrown over both lines of rails and their stages; in fact, the passengers should be entirely under cover from the time of leaving the vehicles which bring them to the station, till the time the train takes them away. This occasions very little expense, and is a great addition both to health and to comfort.

For such a station two clerks would be required, one for passengers, parcels, and private carriages, the other for goods. The mode of conducting the business we shall advert to in its proper place. An inspector, and about four policemen, with porters, according to the extent of the traffic, would probably be sufficient; the whole should be well lighted up with gas, if it can be conveniently got; and it would much conduce to the comfort of the passengers, particularly ladies, if a decent female attended in the waiting-room, and had for sale pastry, biscuits, or sandwiches, with lemonade and ginger beer.

Great care should be taken at each out-station, that the following things can all be simultaneously performed, viz. First, that the train can be setting down passengers on the one side who are going to remain; secondly, taking up passengers on the other side who are going on, and this on both lines; thirdly, that the engine can be taking in coke and water, and also raking her fire, for which purpose, a small coke store should be built close to the water crane, and an ash pit properly excavated in the requisite position; and, lastly, that horses and private carriages can be in a situation to enable them to be attached to and detached from the train, at the same time as the other things enumerated above are being done. It will also be requisite, that the same care be taken at the goods' station, but goods' waggons should also be able to be attached to and detached from passengers' trains, as they will often be useful, when the traffic in passengers runs a good deal one way, in completing the load of the engine, and economising the outlay in locomotive power.

To explain how this is to be done, let us suppose a line of railway running north and south, and that the east line of rails is that by which the trains arrive when going from north to south, and the west line of rails is that by which they arrive when going from south to north. For the east line of rails, the water crane should be so far to the south

of the station, that with an average number of carriages in the train, when the tender is under the crane, the middle of the train is opposite the station house. The position of the crane fixes that of the ash pit and coke store. The passengers alighting get down from the west side of the carriages, and go out from the west side of the railway. The passengers who are getting up, do so on the east side of the carriages, and come to the carriages from the east side of the railway.

The horses and carriages which are to leave the train, must, of course, be at the end of it. These, when detached, are to be run back, or to the northward, where a turnplate should be fixed to take them up by the cross line, to the spot where they are to be landed. This spot, which should be a third line of rails farther east, should be so far to the northward of the station house, that a siding can be run from the third or extra line of rails into the main east line, so as to be clear of the end of the train; and on this siding should be the embarked carriages which are to join the train. On the west side of the railway, there should be another additional line of rails, with a cross line from it to the place where the carriages are embarked. Along this line the goods may be brought. It will be readily seen that all the required objects will be effected by this arrangement.

For the western line, the water crane should be sufficiently to the north of the station, to allow the centre of an average train to be opposite the station-house, when the tender is under the crane. The ash-pit and coke-store are, as in the previous case, regulated by the position of the crane. The passengers who are leaving the train, get out on the eastern side of the carriages, and leave the railway also on the eastern side. The passengers who are to join the train are waiting on the western side, and get into the carriages on that side. The horses and carriages which are to leave the train, are run back to the southward, past the siding from the west additional line by which those come on which

are joining it, and are brought back to that siding, when clear of the carriages joining the train. By the siding they get on to the west additional line, and going to the northward, are taken across as soon as the train has left, and are disembarked at the proper spot.

Goods joining or leaving the train are managed exactly in the same way. Those which are to leave it being run back on the main line, till past the siding by which those come into the main line which are to join the train ; and when these are clear, those which left the train are to be brought to the siding, and run into the goods' station. Proper waiting rooms for the passengers should, of course, be provided on each side of the railway, and their exit and entrance will be by stairs, either up or down, as the station is situated on an embarkment or in a cutting. A foot-bridge may sometimes be thrown across with advantage.

There is such a decided convenience in having all stations on a level, that we should strongly recommend them to be placed so wherever it is at all practicable, even if there is some little sacrificed in another point of view ; but this is a matter which will, in general, be so completely governed by the localities, that it may not be possible, in many cases, to attain it. When this happens, however, great care must be taken to make the approaches wide, and of a gentle slope.

They should be well lighted in every case, and particularly where the baggage is loaded and unloaded, or the horses, carriages, or goods taken off and on. In order that marks and directions may be readily seen, every eccentric for moving points should have a light, and, in general, the error will be in having too little light, and not too much. Gas and water-pipes should never cross the lines of rails, when it can, by any possibility, be prevented ; but as this must sometimes happen, we strongly recommend that, in every case, they should be laid through an outer casing of iron, at least two feet in diameter, where they go under the

rails, so that the rails can be adjusted without any risk of injuring them, and they can at any time be taken out or repaired without disturbing the rails. See Plate CCCCXXIV. fig. 1, in which *a* is the guard pipe in section, *b* the water main, *c* man-holes for entrance to the guard-pipe, and *d* the drain from the man-hole to the culvert. Where there is either a sufficient head of water, or a pumping engine, advantage should be taken of them, and fire plugs laid down, so that flexible ropes can reach every part of the station, and these should be worked once a-week.

The tank for containing the water, if there be a necessity for one, may be placed on the top of the pumping engine-house, from whence it should deliver the water into two cranes, one for each line of rails. The horizontal arm of these cranes should swing round, so that their mouths, furnished with a leather hose about three feet long, can come over the tender; they should open and shut by means of a conical valve, worked by a screw, the handle of which should stand out at the end of the horizontal arm, (Plate CCCCXXV. fig. 1.) If a spring of water can be found, a small tank may be placed on brick-work, a little higher than the tenders, its size being regulated by the supply and demand.

The locomotive engine-house should be furnished with a forge, work-bench, and a couple of vices, so that small repairs can be done, and also have a place to hold coke; and the carriage shed should have water laid on to it, which will be required for cleaning the carriages.

The most complete contrivance for this purpose, is that by Mr. Rofe, the engineer to the Birmingham water works, who also planned the above-mentioned guard pipes. It is now in use at the Birmingham railway station, (Plate CCCCXXVI. fig. 1.) where it answers very well; it consists of a cast iron upright fluted column, about three feet high, and six inches in diameter, ending at the top in a globular head. About twelve inches from the top, two arms *a*, *a*, stand out about ten inches, attached to each of which is a saddle-cock

fitted with a hollow plug, and moved by a lever handle; a leaden pipe comes up this column, and is connected to each of the cocks by a union joint, as shewn at *b;* the globular head contains an air vessel *d* and *e*, *e*, or the whole interior between the iron column and the leaden pipe is packed with coke or charcoal dust, which, by being a bad conductor of heat, prevents the water from freezing in the most severe weather. The column stands on a stone base, from which runs a drain to carry off the waste water, fitted so that it can at all times be readily opened to be cleared from any obstruction; *e* is the feeding pipe, *ff* show the holding down pins, and *g* is the hollow cock plug.

These out-stations are very apt to be too long forgotten; they should be begun in time, and the most advantageous way is to let them by contract to some respectable builder in the adjacent town. In fact, we are not certain, whether it would not always be for the best to subdivide the whole work of a railway, and let it by contract in small portions, this would admit all the hard-working class of sub-contractors, who now take the work under the large contractors. We know one line of railway on which this is done, and the result has been a considerable saving. It would, however, demand the most unceasing exertions on the part of the engineers.

That end of the line where the smallest portion of the traffic is, will not require a much larger station than what we have described. Here, however, two waiting rooms must be considered as indispensable, a first-class one, and a second class; and the locomotive engine-house and carriage shed should be proportionally larger, possessing the means of doing small repairs to the coaches; but all constructing and repairing should, as much as possible, be done at the principal terminus, both as it respects engines and carriages. For this purpose, a disabled engine truck, and a disabled carriage truck, should be made, on which they could respectively be forwarded, when seriously damaged, to the general repairing yard.

It is at the station where the principal terminus is that the greatest care is requisite. We shall first state what things are required, and then endeavour to put them in shape, so as to arrive at convenience, respectability, and moderation in price.

Let us suppose two buildings, 195 feet long, placed parallel with four lines of rails, laid down between two platforms, which platforms adjoin the building on one side, and the exit road on the other. The length of the platforms must be about 400 feet for a first-rate railway; and the whole of this space between the ranges of buildings, and farther on to the end of the platforms, should be roofed in, say 103 feet wide, which will allow 30 feet in width for each of the platforms, and six feet between each of the four lines of rails. The right-hand building will contain as follows, the width of each building being twenty feet. (Plate CCCCXXVII. fig. 1.)

Ground Floor.	Length
Booking office	30
Two waiting rooms	80
Agent for coaching	15
Clerks to do	15
Lamp and grease room	15
Parcel office	20
Total length	175

Upper Floor.	Length
Audit office	15
Finance do	15
Correspondence and minutes	15
Secretary	20
Waiting room	15
Board room	30
Engineer	20
Lost luggage	15
Porter's waiting room	15
Police office	15
	175

Two passages 10 feet each complete it to 195 feet.

The booking office should be placed parallel with the departure line, and should have two entrances and two exits, with a partition in the middle up to the counter, and side rails at each end, so that the two classes of passengers cannot

be mixed till after getting their tickets. Plate CCCCXXVII. fig. 2 in elevation, and fig. 3 in plan, where *aa* is the counter, behind which, at *b*, are the booking-clerks for second-class passengers, and at *c* those for first-class. These passengers enter respectively at b' and c', and go out, after receiving their tickets, round b'' and c'' to the doors b''' and c''', at each end of the booking office into the two passages, and thence on to the platform, or into the waiting room, as they please; the second-class waiting room being on that end of the platform next the engine, and the first-class at the opposite end of the booking office. The booking office should be fitted with counter, desks, weighing machine, a clock, strong box, &c. The second-class waiting room should be furnished with two tables, and benches all round; the first-class with chairs and tables, both being supplied with hat and cloak pins fixed over receptacles, for wa er draining from the articles hung on them. The agent's room, and his clerk's, should be fitted up with the ordinary fittings in a clerk's office.

The lamp and grease room should be fitted up with pins all round, on which to hang the roof lamps, and racks for the head and tail lights, with a dresser and drawers; the dresser being covered with lead, and laid sloping to a corner, where there should be a drain to carry off the spilt oil into a proper receptacle below.

The parcel office should be furnished with a counter, long desks with drawers, and a patent lever weighing machine.

The audit office, finance office, and correspondence and inventory office, may be all fitted alike, with the number of desks in proportion to the number of clerks to be employed in each. The engineer and secretary will most likely fit their rooms, and the board room and waiting room to their own taste; the lost luggage room need having nothing but hooks to hang up cloaks and other things, and part of this may be used as the head porter's office. The porters' wait-

ing room should have lockers all round it, each man having one with a lock and key to keep his brushes and cloths in; the police office should have hooks for the police staves and handcuffs, with a large-sized desk, table and stools, and a desk in this office should also be appropriated for the guards, in order to extract their reports from their journals.

In each room where papers of consequence are kept, there should be a set of iron safes, six in number, placed two and two in oak cases, each case holding six, by means of two shelves; these safes should draw in and out on rollers, and the case should never be locked. The object of this arrangement is, that, in the event of fire, no locks would require to be broken, nor any time lost in waiting for keys. Whoever came first on the spot, could draw out the iron boxes, and drag them to a place of safety, with all which they contained; and as the iron boxes themselves should always be carefully locked, the grand object of security would thus be obtained.

A covered gallery should go along the whole length of this building, at the level of the upper floor, with stairs at each end, by which the various offices should be approached, the police, porters, and lost luggage being entirely confined to one of the stairs. Two internal stairs may also be had out of the 20 feet allowed for the passages, if thought necessary.

The building corresponding with this should have all its doors on the side opposite to the arrival platform. The lower floor may be used for a receiving and delivering goods' office, and a storeroom for heavy articles, and the upper floor for the remaining offices in the goods' department, for stores of a lighter description, and for the clerks' offices in the store department, also for the residences of the housekeeper and superintendent of police. This building is shewn at *b*, Plate CCCCXXVII. fig. 1.

The following arrangement would answer every purpose:

Ground floor.

	Length.
Goods, in office,.......	30
Do. out,...............	30
Stores,....................	95
Store-keeper,..........	20
	175

Two passages 10 feet each, below.

Upper floor.

	Length.
Housekeeper's sitting room,.................	20
Do. eating-room,......	15
Do. kitchen,..........	15
Do. bed-room,.........	15
Goods' office, general,	20
Store office,............	15
Stores,..................	30
Police Superintendent's bed-room,...........	15
Do. kitchen,......	15
Do. eating-room,	15
Do. sitting-room,	20
	195

At the inner end of the platforms the ground should be of the same height as the platforms are, which ought to be that of the bottoms of the carriages. The departure line should run up this space about 100 yards, the ground being excavated for the purpose, or the retaining walls may be built before the space is filled in. It is up this gullet that horses and carriages are embarked, for which purpose, and to increase the facility of shipping the carriages, a siding may be run out, so that two at a time can be taken upon the trucks, which should be so fitted as to come up with their inclined planes, exactly flush with the road. If the buffer rods prevent this, inclined planes must be attached to and project from the road, turning on hinges to connect the road and the carriage truck. The horses, as they are taken in sideways, can have as many boxes filling at the same time as to enable a very large number to be received in a very short period. This gullet and its siding are shewn at *e*, fig. 1, Plate CCCCXXVII.

At the end of the booking offices, nearest the town, the coach-house for the first-class carriages *e*, and also for the

horse boxes and trucks, may be placed, at a distance just sufficient for a siding to be run to the departure line, which would be about 60 yards; and at the opposite end of the booking offices the coach-house for the second-class carriages *f*. Then each class and the horses and carriages will be run on the departure line in their proper place in the train, without the intervention of any turnplates, by which a very considerable saving of time, money, and trouble, will be effected.

The larger these buildings are the better. At any rate they, in conjunction with the two spare lines of rails under the passenger shed, should contain all the company's carriages that may ever be at the station at one time. If they do not, a very great expense will be incurred, from the rapid deterioration they experience from exposure to the weather. The upper floors of each should form the repairing shops and painting shops, the carriages being weighed up by cranes. These shops should of course be fitted up with all the necessary benches and tool-chests.

The floor should have as many lines of rails as it will conveniently contain, in directions parallel with those under the shed, and should have these crossed at right angles, at the end next the siding which leads on to the main line, by the contrivance which may be called Brunel's slide, from the name of the inventor, or more properly perhaps, Kennedy's. This admirable auxiliary to a railway, which entirely supersedes the use of turnplates, except in extraordinary circumstances, must now be described.

Conceive ten, or in fact any number of lines of rails parallel with each other, and any given distance apart, and let a length of ten feet of these rails be taken out at the end of the station, right across the whole lines, and the ground excavated about two feet down; let a line of rails be then laid down in this trench, and on this cross line let a platform run on rollers about two feet in height; this platform is to have two rails of ten feet long laid on it, and fixed at the same distance as each of the ten lines of rails, so that if the height

has been properly attended to, this platform and its rails being rolled to the end of any one of the ten lines of rails, exactly fills up the chasm, and completes the railway. Hence, when carriages are wanted to be got from one line to the other, it is only necessary to roll the slide on to the line where the carriage is, roll the carriage on to the slide, then roll the slide, having the carriage on it, to the line where the carriage is required to be placed, and the thing is done. The ease, convenience, and rapidity with which this is accomplished, is truly delightful; and the railway world ought to hold themselves deeply indebted to its inventor. A good turnplate will cost at least L.120, and requires frequent repairs, whilst the above simple contrivance will hardly require any repairs at all, and its first cost is not near that of one turnplate, although it performs the duty of so many.

Opposite to the first-class carriage-house a corresponding building may be placed, *g*, and fitted up for stables for the goods' horses, with harness room and hay lofts on the upper floor, together with some rooms as a residence for the man who has charge of the horses.

Opposite to the second-class carriage-house may be placed the waggon-house, *h*, and its repairing shop above, with a siding on to the goods' departure line, and the before mentioned slide on the side of the building, next where the siding comes in. The goods' lines must have their slide across the end next the waggon-house, and the passenger lines must have the same thing at the end next the first class coach-house. Two slides in each place will be advantageous.

Farther on than the stables and first-class carriage-house, and right between them, may be placed the engine-house, *i*. The handiest form for this is for it to have sixteen sides, by which means it will then hold fourteen engines, and leave the road free. The engines with their tenders would run on lines of rails into fourteen of the sides, where they would stand till wanted; and by means of a large central turnplate

communicating with all the lines, they could be moved from any one place to another. The central turnplate should be of such a size that the engine and her tender can always be moved on it without detaching them. It may be turned by an endless screw and winch handle, if it be thought necessary.

In front of the engine-house may be attached a coke store, and above, the water tank may be placed. On the outside proper ash pits should be provided; and inside, pits three feet deep, with drains from them, should be made under each engine, to enable the engine-men to examine, clean, or repair them. Similar pits should run under both the arrival and departure lines in the station, to enable the carriages to be examined, and also in the carriage and waggon sheds. In the angles of the engine-house forges may be placed, and along the side, benches can be fixed. The engine-house benches, forges, and pits, should be well lighted with gas, if possible; each bench-vice, and each pit having a light from a three-jointed branch, so that it can be moved every way.

Water should be laid on between every alternate pit, and a hose of Macintosh cloth and pipe be furnished, so that on both sides the engines can be either washed or filled. Supplies should also be laid on for filling from the tank, the water in which may be warmed by the waste steam of any fixed engine near the spot; and these should come down to water cranes standing in the entrance, with good drains under them. (Plate CCCCXXV. fig. 1.) Spacious blowing-off places should be placed outside the engine-house, with large waterways. In fact, the whole station should be most thoroughly drained in every part. The water cranes should have a lamp fixed to them at the out-stations, to shew a white light when the crane is turned off the line, and a red one when it stands across it.

A similar building to the above engine-house should be built about fifty feet from the first at *k*, the lines of rails being continued into it, the intermediate space *m*, being formed into

a store-house. This second building should be entirely devoted to those repairs which are considerable, and to making new engines, and should be fitted with turnplate pits, lights, and water, exactly as the other; and through it, opposite to the store-room at *n*, may be the lathes, worked by two steam engines, whilst at the other end, on one side of the first entrance to the engine-house, at *o*, may be the coke ovens, and on the other side, at *p*, the pumping engine; the four chimnies, which are shewn by the small circles, corresponding with each other, and the whole building having a symmetrical appearance, as well as being adapted for its use.

On the outside of the offices for stores and goods at *q q*, may be any required quantity of shedding for the goods' department, with its arrival and departure stages, on the same plan as those under the passenger shed, except that here more space will be required. The entrance road is at *s*, and the exit road at *t*.

By such a station as this the use of turnplates is entirely avoided, except in the engine-house, and to disembark the private carriages; the saving in time through this would be immense, as well as the saving in money; but the time is the principal thing. Private carriages, for instance, might be embarked up to two minutes of the instant of the train starting, which could never be done if turnplates had to be used.

In the front of the booking offices, workshops, *r*, for the construction department may be erected, which, when the requisite number of coaches, trucks, waggons, and horse-boxes are made, may be converted into warehouses. As the waggon-house would be sufficient for repairs and future constructions, or they may be divided into rooms, and let as residences to the police porters and night watchmen employed on the station; this would not only ensure their being on the spot, but would shorten the time of absence to their meals.

If there happens to be a good head of water near, it will be well to take advantage of it. At Birmingham, for in-

stance, the pressure is such, (about 180 feet), that in the engine-house, by attaching any of the hoses between the pits to the engines, water can be forced into their boilers when the steam is up. Those who have had to do with locomotives will easily appreciate this advantage; and we are of opinion, that on leading lines of railway, it would be worth while to build the necessary tanks, so as to accomplish this object, raising the water by an engine. The mode of fitting up the above water apparatus, is shewn in Plate CCCCXXIV. fig. 2, where *a a* are the main water pipes; *b b* air-vessels placed over them to prevent the ram of water bursting them when the cleansing and forcing cocks are shut too suddenly; *c c* the cleansing and forcing cocks, to which the hoses are attached, by means of which the engines which stand over the cleansing pits, *d d*, may be washed, and the boilers filled immediately, each hose serving two pits; *e* is the central turnplate from whence the rails branch off to each pit.

We do not mean to say that this plan of a station reaches perfection, and those only who have tried to lay one out will know how difficult it is to bring all the elements together in an advantageous way; but we think the balance is on the side of the advantages, particularly as no turnplates have to be used in getting the engine either on or off either line. In all cases a weighing machine should be fixed, of such a construction and in such a situation as to allow the weight of the engine, tender, and each carriage, to be taken as the train starts. In order to see clearly into the general arrangements, let us now go through the process of dispatching and receiving a train of passengers and one of goods.

Supposing, then, that the usual train, say four first-class carriages and four second, are standing coupled together alongside of the departure stage, the passengers begin to come in, and it soon becomes evident that an unusual number will arrive for this train. One minute will suffice to run a first and second-class carriage from the respective coach-houses into their proper situations at either end of the train.

Two minutes will allow two of each to be put on; and this will provide for 48 second-class passengers and 36 first-class, an allowance that will most probably suffice for almost any mere contingency. The influx of passengers may perhaps be occasioned by some fair in the neighbourhood; and five minutes before the time to start a string of horses come down for the fair. The gullet will embark 30 horses in about two minutes, for boxes to contain that number can stand in it, and the siding being long might always be kept with a number standing in it. Private carriages, two at a time, can also be shipped, and all this may be kept going till one minute before the hour of starting; for with active men one minute will suffice to run them down the gullet and couple them together.

When the bell rings for the passengers to take their seats, the engine will come along the arrival lines till it gets to the siding by which it enters the departure line, and takes its place at the head of the train, and when the clock strikes the train moves on. At the arrival of a train every thing is just as simple. The engine unhooks and proceeds straight to the engine-house; the passengers get out on the stage at its upper end, where there is a carriage road for their use; the horses are taken out at the lower, whilst the carriages are taken to the turnplates, and this is the only unpleasant part of the work.

For a goods' train the waggons are brought as they are wanted out of the waggon-house, and loaded, and the engine comes out as before, and gets on the goods' departure line by a siding, as usual, to take away the train. On the arrival of a train of waggons, the engine must slacken its speed at the part marked (*a*) on the plan, and tow the waggons into the station by a rope, the engine itself going on to the second line of rails, so that it can return to the siding, and proceed to the engine-house directly it has performed its duty.

Having shewn the advantages of this arrangement, we

have now to look at the disadvantages. These consist in using the passenger arrival line as a passing line for the engine to the departure line and the goods' station, and the towing in of the waggons by a rope on the goods' arrival line. This last is a common mode of proceeding, but there is a loss of time. The former could at once be obviated by giving up one of the spare lines in the passenger station as the engine line, and running a siding from it to the departure and arrival lines; but we think that so little is lost compared with what is gained, that we should not hesitate in adopting this or a similar plan. Of course there are many modifications which would have to be attended to, according to the nature of the ground, the convenience of exit and entrance to the station, and other matters which can only be decided on the spot; but all we intend is to look to the general features.

The second plan which we give of a principal station is a very excellent one for those who would prefer the use of turnplates; it is in fact as convenient as can be desired, and admits of considerable architectural effect. (Plate CCCCXXVII. fig. 4.) The offices might be appropriated as before, except the goods' offices, which must necessarily be near the goods' station, but their room will be taken up with the arches through which the passengers would proceed through *b* to the road from the arrival stage.

We have been thus particular respecting stations, from their vital importance, and the necessity of their being begun early. On them depends, in a great measure, the well-working of the railway, for it must be recollected that, at any other time than that of receiving and dispatching the trains, there is hardly any thing doing in the passenger shed; and if the station be so arranged that the men, instead of being idle all the rest of the day, could be turned on to the goods' station, this would be so much clear gain. Either of the plans we have given, would admit of this, and it is essential to a proper economy.

As the works proceed towards completion, so many causes

will arise to engage the engineers and directors, even without the occurrence of any particularly great accidents, that on all the leading questions time should be taken by the fore-lock. Springs of water, rock, and quicksands, will be met with where least expected perhaps, and the constant exertion of every talent will be required towards the close of the works. Good drainage will be most wanted when least at command; and work done with wet materials will be always slipping. Many times have embankments made of wet clayey earth slipped at all kinds of slopes; and although hundreds of cubic yards of dry material have been tipped on to them, they have been swallowed up and totally disappeared, whilst, at last, the only remedy to be found was weighting the slip itself with a sufficient quantity of earth to enable it to bear the embankment above.

When rock occurs at any height up the sides of an excavation, advantage may sometimes be taken of it to decrease the expense, by cutting only a sufficient width for the railway, and having no slope to the earth below the rock, but building up retaining walls from the railway below when bottomed out to the rock above, or what is called undersetting, an example of which may be seen at the great Blisworth cutting on the London and Birmingham railway. (See Plate CCCCXXVI. figs. 2, 3, 4.)

It will often happen that many parts of the permanent way are laid prior to its being possible to open either end of the line for traffic. These had better be kept in repair by the contractor; but when the line is once opened, or any part of it, for the purpose of travelling, it will be much the best way for the company themselves to keep it in order, taking especial care that the contractor repays them a proper price for so doing. The consequences of any accident by the engine or carriages getting thrown off the rails are so frightful, that no attention and expense can be thought too great which can prevent such an occurrence. We have seen instances in which carriages have undergone so complete a

smash, that not a square foot of plank could be picked up anywhere.

A set of plate-layers consists of nine men for turnplates; twelve for laying rails; five for repairing the way; and six for laying in points and crossings.

To each set, the following tools will be required:—

2 chissel-ended crowbars for drawing spikes.

1 point-ended crowbar for moving rails, the point being put in the ground.

1 claw-ended crowbar.

2 swivel or cramp crowbars, similar to a tooth-drawer, for drawing spikes without heads.

4 pick axes.

4 beaters or wooden picks for ramming ballast under the sleepers. (Fig. 33.)

1 beetle, 6 inches diameter and 20 inches long, for drawing down sleepers. (Fig. 28.)

2 levers. (Fig. 31.)

1 cuddy or three-legged stand for the levers, so called from the name of the inventor. (Fig. 25.)

12 block drills.

4 hammers to ditto.

4 keying hammers.

2 chipping hammers.

1 sledge hammer.

4 cast-steel chisels for cutting joints.

12 $\frac{5}{8}$-inch augurs.

1 handsaw.

1 axe.

2 adzes for trimming the sleepers to receive the chairs. (Fig. 30.)

2 guages for the distance between the rails. (Fig. 26.)

2 sets of sights. (Fig. 32.)

1 hand-drill for drilling turnplates.

4 sets of chisels with wood-rods for handles, similar to blacksmiths'.

2 files to file the joints.
2 shifting wrenches for screwing up seats.
1 spirit level. (Fig. 27.)
1 turnplate to trim the sleepers to.
4 punning rammers. (Fig. 29.)

Fig. 25.

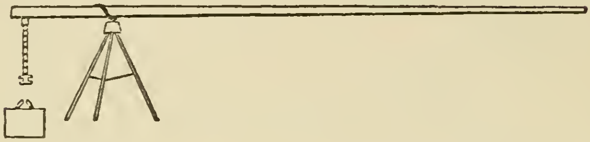


Fig. 26.

Fig. 27.

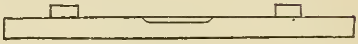


Fig. 28.

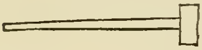


Fig. 29.

Fig. 30.

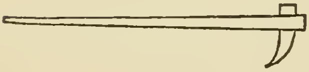
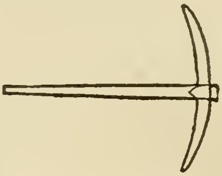


Fig. 31.

Fig. 32.

Fig. 33.



The foregoing tools will enable them to fit in points and crossings, switches or turnplates, as well as to lay the line. Of course when there are sets of plate-layers wholly working at blocks, and other sets wholly working at sleepers, the tools which do not relate to the work they are engaged

in, may be kept back. The above list has reference to chairs having wooden keys; for any other kind of chair, if necessary, an adequate alteration must be made. One standard guage should be kept in the engineer's office for the width of the rails, and another for the width between the lines, and all others constructed from it; and they ought to be made of iron.

The best plan to be pursued in laying the permanent way, is for the resident engineer in the first place to set out the lines as to their bearing, driving in pegs to mark their direction. The number of these pegs will depend on the qualifications of the plate-layers; a bad plate-layer will require a peg at every chair, whilst a good one will not require more than one at every eighth chair. The second thing is to put in pegs to denote the level; from these the plate-layers work, and particular care should be taken that the whole is done to the greatest nicety. In the next place, the plate-layer measures off the exact position of the four rails, putting in more pegs if he likes, transferring the engineer's level on to them and driving them down till they are right; then the joint blocks or sleepers are laid, and the sights are placed on the rails, one at the last level, and one farther along the line, and to these two the one on the newly laid rail is to be brought in the most perfect manner, ramming the ballast under the blocks and sleepers, and thumping them down as hard as possible. A wooden beater is the best when the ballast is sand; and when it is gravel or rock, the iron pick with a hammer head should be used.

It is generally considered as best to incline the rail a little, in fact equivalent to the cone of the wheel, so that the wheel may rest on the whole surface of the rail; if it do not, the rail and wheel will both get very quickly cut. This inclination may be effected by sloping the blocks and cutting the sleepers, for which a template must be given, or the proper allowance may be made in casting the chair. This sloping does not affect the legitimate action of the coned

wheel; and proper guages for the inclination should be made, if it is to be effected in the casting of the chair. Spirit levels will be found extremely useful in laying the way, and they might be made with a moveable bottom, so that one end of the level might be raised above the other, the height for the various inclinations being marked on a scale at the end. They are also useful for shewing when both rails are the same, or any required height.

In repairing the way, it will require one overseer to from four to eight miles, according to the state the permanent way is in ; and under him is a foreman with a time-keeper, and from three to six men per mile, furnished with red flags and red lanthorns to fix in the ground when the road cannot be passed. The overseer attends to the state of the fences, buildings, bridges, and every thing on the line ; the policeman should also report any thing wrong ; and it will be found best to have neat houses about one per mile for the police and plate-layers, switchmen, gate-keepers, &c.

Repairing the way is of such vital importance, that no pains or expense should be spared to keep it in the most perfect order. An excellent plan for inspecting the guage of the rails, is the following : A simple carriage frame with four light wheels, made only sufficiently strong to carry two persons on a board hung from the axles, low down, should be fitted with the contrivance to be now described. Two rods should be fixed with horizontal rollers at their lower ends, each taking against the inside edge of the rail, and forced outwards with a moderately strong spring ; the upper end of these rods should work two inverted levers ; the ends of these levers which have the greatest motion, should travel in and out along a scale of inches, and these registering ends should move about twice as much as the lower ends of the first mentioned rods. They may be made to mark all the irregularities with a pencil, on paper placed on a moveable cylinder, turned round by a connection from the carriage wheels, if thought necessary ; so as to present at

the end of the journey, a record of the whole state of the road. A roller acting in the same way on the top of the rails, will similarly indicate where the level of the line is faulty.

When it is desired to inspect the guage of the rails, the carriage is placed on them, and the resident engineer takes his station at the scale. His attendant then pushes the carriage forward, and the rollers at the lower end of the rods being pressed by the spring against each inner edge of the rails, the upper ends of the inverted levers connected with the rods, show on the scale twice the error which there is in the guage of the rails in every part, as the carriage proceeds forward. The engineer should be provided with proper stake rods to fix in the ground at all those parts where the guage is so faulty as to require alteration. Some of these stake-rods should be painted red, to be put in at very bad places. The plate-layers should follow on each district, and commence the necessary repairs, the overseer of the district keeping by the carriage, in order to note down the red stakes, to which he should forward the plate-layers as soon as his district has been examined throughout, taking especial care to direct their attention to the worst places, which should receive instant attention.

Great care should be taken that the engine-men, who are employed to ballast the line under the directions of the resident engineer, as well as those who work the passenger-engines, are furnished with the most precise and definite instructions for their guidance in the performance of this duty, or the most serious mishaps may arise; and the respective engine-men should send to the resident engineer a daily report, containing their names, the name of the engine, its station, time of departure, number of waggons conveyed, where to, time of arrival, cause of detention, if any, name of any passengers who may have been carried, name of the person who gave these passengers a pass, and the expenditure of fuel, water, and all other materials.

The trains always taking the left-hand line, according to the old rule of the road, no ballast-engine should be suffered upon any account to go on the right-hand line, except when crossing for the purpose of going into a siding, and this only under such restrictions as will, under any circumstances, prevent the possibility of danger. No ballast-engine should be allowed to stand upon the main line, but always on a siding, so as in no way to interfere with the regular transit of the trains; nor should they be kept in any situation without some person to take charge of them. They should never be allowed to pass along the line except during the periods fixed by the resident engineer for that purpose, which should be arranged with the secretary so as to suit the passenger and goods' trains.

No ballast-engine should ever approach within a quarter of a mile of any other engine, except it is expressly summoned for assistance in case of any accident, nor should they ever pass along the line without a dispatch note signed by the resident engineer, stating the time they are to be out, and the service to be performed by them, being in the possession of the engine-men. The engine-man and fireman should be the only two persons on the engine and tender, and any engine-man allowing a single person to be conveyed from one point to another on the line, except those he may be ordered to carry by the resident engineer, or unless they are persons in the company's pay, for the purpose of attending on, or taking charge of the waggons or engines, should be invariably fined, and for the third offence discharged at a moment's warning. This should not of course apply to the directors, nor to any properly authorised officer of the company.

The engine-man should always stand by his hand-gear whilst the engine is running, and keep a most vigilant look out before him, passing all out-stations or stopping places slowly, and upon discovering any train at a stand still, he should approach and pass it at no greater speed than three miles an hour. Should any train require the assistance of

a ballast-engine, it should be immediately given on an application to that effect from the upper guard, the engine-man first placing his waggons on a siding; but the ballast-engine should not draw the train any farther than is necessary to place it under the charge of a regular passenger or goods' engine; and it should then return to its waggons in such a manner as not to interfere with the next train coming along the line. Every ballast-engine should be provided with proper spanners, and other requisite tools, for the safe custody of which the engine-man should be responsible. During a fog the engine should be moved slowly, and the whistle be blown at not greater intervals than a quarter of a mile. Fogs, however, will always be dangerous on railways till two whistles totally different in sound are used, one for each line, blowing by machinery at every eighth part of a mile. When the ballast-engines stop in a fog on the line, the fireman should be sent at least 400 yards a-head to look out.

It is the duty of the engine-men to take care that the engines are in a proper state of cleanliness and efficiency before they quit the engine-house, that every part is in proper and complete working order, and that the regular supply of coke and water is in both the engine and the tender, together with the requisite quantity of oil and waste; and he should personally inspect his tool-box, and ascertain that every thing is in it which by rights should be so, and that his shovels, rakes, &c. are in readiness. He should carefully examine all his oil cups and syphon wicks, his water guage, and every other part of the engine, and when he sets her a-going, try his pumps on both sides, and also his hand-gear. According to the distance the engine-house is from the point where he hooks on the train, time must be allowed him before the minute of departure sufficient to let him arrive at the required spot about one minute before he is wanted, and no more.

He should be very careful in bringing his engine down to the head of the train, where the connection should be

made by a man specially appointed for the purpose. He should leave his condensed steam cock open as long as he can, being very cautious that it is shut just before the time of departure. During the journey he, in conjunction with his fireman, should keep a vigilant look-out for all signals of danger, watching each policeman as he approaches him till he has made his notification that all is in security along his part of the line. He must be attentive to stopping the train at the places ordered, and that he does not exceed the regulated speed, considering correctness of arrival his greatest aim, and consequently making up as far as he can in one part of his journey for any unavoidable detentions which may have arisen in other parts.

He should be very attentive to his water-guage, and test it, whenever he thinks it necessary, by his guage-cock. This, however, should be done as little as possible if he have confidence in the water-gauge. He should never use his pumps without turning his pet-cocks, and ascertaining by them that every thing is working properly for the injection of the water; particularly when one pump has got out of order, that if any thing should happen to the other he may instantly stop the engine and examine both of them, the necessary tools for which should be in his tool-box. He should always when practicable take the opportunity of pumping in water when going down inclinations, or at other favourable times. He should attend well to his rakings, and should be careful not to put on too much coke at once, unless he is very strong in steam; he should be constantly alert to the signals from the guard of the train, and ready to stop it in the shortest possible time when ordered to do so. The guard should have a check-string to the arm of the engine-man, and a flexible hollow tube should be fixed from the guard's carriage to the engine, through which the men can converse, which the noise of the engine and train will otherwise render difficult.

After completing his journey, and placing his engine near

the engine house over the ash pit, he should see the fire carefully raked out, and if his engine requires blowing off, he should take it to the proper place for doing so, and then apply for the necessary assistance to place it afterwards in the engine-house. But if it should not require to be blown off, he must of course proceed to the engine-house as soon as his fire is out, and having placed his engine in security, he should make his report to the foreman of all circumstances relative to the journey, and of any defects in the line, or in the engine, that he may have noticed, and the correct cause of all detentions which may have taken place. The engine should be examined and cleaned by proper persons appointed for that purpose; but this should not supersede the necessity of the engine-man personally investigating, before he starts on a journey, that every thing is in correct order. A great deal of expense in cleaning engines, as well as in their wear, would be saved by using a tarpaulin covering down each side from the boiler, to protect the machinery from rain. The engine-man should also have a fencing from the wet over the place where he stands.

The resident engineer who takes charge of the line when opened, should draw every thing by requisition from the storekeeper. The overseer should, in the first place, make out his weekly pay-bill, which should be checked by the time-book of the respective timekeepers; and when signed by the engineer, it should be forwarded to the audit-office, and the pay sent down to the booking-clerks of the adjacent stations, who should pay the men in the presence of the overseer, each man signing his name to attest the reception of the money. The necessary clerks and draftsmen for this part of the engineering department should also be paid weekly in the same way.

The resident engineer, in the arrangement of his office, will find it very convenient to have files hanging up for the most common forms of papers which are in use, such as the overseer's pay bills for each district; the time-keeper's returns, also in districts; invoices with the most usual trades-

men's names on them; orders received, which when executed are transferred to orders executed; certified accounts; police reports of bad places in the road; locomotive power reports, store accounts, and many other things which the nature of the daily transactions will at once point out. These files will be best made of pasteboard, of a foolscap size, with a wire through them about one-third down, bent up to form a retainer for the papers, and a hook for the whole.

It is well worth considering whether, by an increase in the police force, and making the men employed in it all perform the office of repairing the permanent way, a considerable saving might not be effected in the hitherto enormous expenses of keeping a railroad in repair. We are yet too much in a state of infancy, as regards these things, to see clearly our way in their management; but it would be well worth the trial whether, by a combined system of this kind, the road would not be better sustained, as well as looked after, than it is at present, where about one man per mile is solely employed in using his eyes, whilst he might, by the above method, use his hands also; a decrease in the wages of the men on any district being made whenever any extra assistance has to be sent on it.

On the London and Birmingham railway, the directors, with a view of inducing the overseers, foremen, and plate-layers, to use every exertion in getting the permanent way into the most perfect order, are trying the system of premiums. The line is divided into lengths, as we have before described, each being under an overseer, and on the most difficult parts of it, a reward at the end of three months is to be paid to one overseer out of every five, and his men, as follows:

	Overseer.			Each foreman.			Each plate-layer.		
For the best length	L.5	0	0	L.3	0	0	0	10	0
—— second best	4	0	0	2	0	0	0	9	0
—— third best	3	0	0	1	10	0	0	8	0
—— fourth best	2	0	0	1	0	0	0	7	0

On less difficult parts the highest premium is omitted, the scale beginning with L.4 to the overseer, and the corresponding prices to the foremen and plate-layers. The foremen's lengths are not to be less than half a mile, and they are not to have more than three plate-layers with them.

The points which are to determine the award of the above premiums, are stated to be, the rails being in perfect line, level, and guage; the ballast being neatly and regularly trimmed, both on the top and at the sides; the ditches being kept clean and at the proper inclination; the slopes properly drained and trimmed; the quick fence well weeded, and the post and rail fence in good order; the roads over the railway level, so as to prevent water soaking through the arches; and the general state of the repair throughout the three months. Any impropriety of conduct towards the police, drunkenness, or neglect in using the red flag, are also to be taken into account.

As the various inclinations on the road become finished, they should be marked on each line, and the marks set as far back as possible, by which means they will be much better seen. The best way of denoting them is to drive a pointed piece of plank into the ground upright, and before this affix another nailed to it at the top, and sloping out from it at the bottom about one foot, the length of the upright being about three feet. The top of this sloping piece should be higher at one end than the other, to show which way the incline is, and the sloping board should be painted white, and have the rate of the inclination marked on it. Upon the other side of the railway the same thing should be done, only the inclined top of the board must slope in the opposite direction, this being regulated by the course in which the carriages travel on the respective lines.

We have never yet seen a good mile mark on a railway, the object apparently being merely to comply with the act of Parliament, certainly not to let the passengers see the miles, for the marks are generally so short, that all persons in the

middle seats of the carriages have no chance whatever of seeing them. What we should recommend would be light iron posts having a box on the top. The box may be made triangular in its ground-plan, (Plate CCCCXXV. fig. 5,) and be about one foot in height, the apex of the most obtuse angle facing the railway. This angle should be so obtuse as merely to allow room in the box to hang a small lamp, and the two sides which form this angle being made of glass, should be painted or ground, except the figures, which are left clear. These shew the miles by day, and the nearest policeman lighting the lamp, they are also shewn at night. Or the planes forming the sides of the triangle next the railway may be of sheet iron, with the figures cut out of it, and merely that portion covered with glass ; in either case the head must have a lid moving on a hinge. The height of these should be just half way up the carriage windows. In the cuttings, the post should be very short, and the mile mark set back on the slope. On the embankments it will be proportionally longer. It may have holes, or other ornaments, cast in its base, serving for steps to get up to light the lamp ; or this may be done with projecting rings, and a slide may be made to receive coloured glass as a signal of any accident.

When such mile marks as these are not adopted, and it is desired to know the velocity of a train at night, this may be readily done whenever the blast pipe of the engine sounds sufficiently loud to be heard, which is generally the case in most engines. The way to ascertain the speed at which the train is going, will be to count every fourth puff from the blast pipe in ten seconds, this giving one revolution of the driving wheels, and the speed will be had by the table on the following page.

The rapidity with which the cylinders of steam are expelled through the blast pipe, would at any common velocity prevent every puff being counted ; but a very little practice will render the counting of every fourth one exceed-

Blast pipe.	Velocity—miles.	Velocity—miles.
Number of fourth puffs in ten seconds.	Wheels, 5 feet diameter.	Wheels, $5\frac{1}{2}$ feet diameter.
15	16·06	17·67
16	17·14	18·85
17	18·21	20·03
18	19·28	21·21
19	20·35	22·38
20	21·42	23·56
21	22.49	24·74
22	23·56	25·92
23	24·63	27·10
24	25·70	28·27
25	26·77	29·45
26	27·85	30·63
27	28·92	31·81
28	29·99	32·99
29	31·06	34·16
30	32.13	35·34

ingly easy, and the rate of going may always be found to the nearest half mile, by those who have only tried this method three or four times. A still easier method, although it will not generally be quite so accurate, is as follows: For five-feet wheels, count the number of fourth puffs in ten seconds and three quarters, and these will be the number of miles per hour the engine is going; and for five feet six wheels, count the number of fourth puffs in eleven seconds and three quarters. The exact number of seconds is 10·7 and 11·78. The method by the tables however is the best.

Paved crossings on a level with the railway are things to be avoided by all means whenever it is practicable to do so; but as some cases will arise where they cannot be done away with, we must render them as little liable to danger as possible. We have given drawings of these, (figs. 35, 36, and 37,) and an approved form of chair (fig. 34), which

Fig. 34.

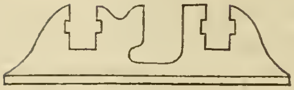


Fig. 35.

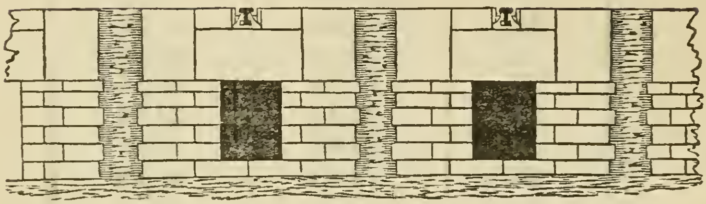
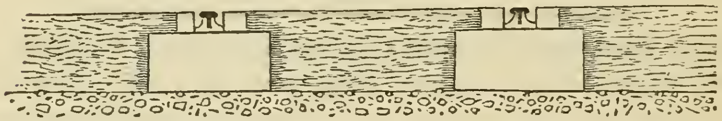


Fig. 36.

Fig. 37.



holds the rail, and also the two protecting irons, which should be laid next to the rails, in order that the wheels of those vehicles which cross the railway may not impinge upon the rails and injure them any more than can be helped. The whole crossing should be well paved with the usual road stones, and there must be strong gates on each side. These gates must be constructed so that when shut they may close up the road on either hand, and when open, may form a barrier across the railway. They should be painted white, and have a large circular red board, three feet in diameter, which, when open, would shew both up and down the line that trains must stop, and when shut would show the same thing along the cross road. A lamp should be fixed to the gate,

shewing a red light along the road in the night, indicating that there is danger; and on the gate being opened to allow any vehicle to cross the railway, the opening of the gate turns the lamp one quarter round, and the red light then shews along the railway, indicating in like manner danger. When the vehicle has passed, all is restored again, and the lamp shews the red light along the road. These gates must never be left without a policeman during the time of the trains running; and he alone should open the gate, having a good lock and key, which he should secure each time. The gates, when open, should fasten with a self-acting catch.

Considerable trouble will be avoided and much regularity attained by having convenient places for the plate-layers to deposit their tools. These should not be farther apart along the line than one mile, and should be large enough to allow each workman and foreman a separate receptacle which he can lock up. The whole building goes by the name of a tool recess. They should be situated in a cutting, whenever it is practicable, and they may be made of wood, if present economy is the object to be studied, but had much better be built of brick, 12 feet in length, 6 feet in width, and 7 feet in height, being sufficiently large to hold all that will be required.

Rails, chairs, blocks, and sleepers should be drawn, when necessary, from the storekeeper. A small supply, however, of each should be kept at every station in charge of the police. If the system of having houses along the line for the police, gate-keepers, switchmen, porters, engine-men, &c., is adopted, which we are certain is the most advantageous plan in all cases, then the tool recess will naturally form a part of these buildings, by which their cost will be still farther reduced. As the tools used by the plate-layers are definite in form and number, each individual implement should have its appointed place, so that they can be immediately got at in the dark if required; and the whole of the tool recesses on the district should be under the charge of the overlooker.

The subject of lamps forms one to which attention is required, and we should recommend all railways to make a red light at night and a red flag by day, the symbols of danger. A green light should be placed at each station at the spot where the engine-man should slacken his speed, and a red light at the point where he is to stop. The police should have hand lanthorns, with a white glass and a red one, which latter can be turned round in an instant, whenever any thing obstructs the passage of the railway; and the light held up at any train approaching, on seeing which the train is immediately to stop. A green glass may also be added, the signification of which would be, proceed with caution; the train should then come slowly on and ascertain the reason for the signal.

For lighting the insides of the carriages, the roof lamps, contrived by the writer of this article, and patented, are the best. The frame is circular, about six inches in diameter, and about nine inches in height; the bottom is formed of a ground glass saucer, which is let through the roof of the coach, the top being protected by a box; on the inside is a small fountain lamp, on an improved principle, which is very nearly shadowless; the whole of the lamp body being above the frame, and the connection between them consisting of a tube $\frac{5}{16}$ ths of an inch in thickness, which tube should always be turned towards the carriage door. These give a soft mellow light, by which the passengers may easily read. They should be used in the day, if any long tunnels are in the line, not only for the purpose of reading, but from the confidence it would give females, who might not feel it agreeable to be suddenly plunged in darkness in company with strangers.

Trains now usually carry head or tail lights to indicate their motions, but the following contrivance is better. On the top of about the centre carriage of the train, an arm should be mounted, moving round upon pivots between two uprights, the plane of motion being at right angles with the

length of the carriage. The length of the arm should be as great as possible, so as only just to clear the lowest bridge, and the most room will be gained by fixing the uprights on the side of the carriage next the centre of the railway. Each end of this arm is to carry a lamp hung in gimballs, with a five inch deep lens before and behind it. On the arm pivot (one of which for this purpose must come through the upright in which the pivot works,) must be fixed a drum, from which a flexible india rubber belt goes over rollers at the edge of the carriage roof and down to another drum attached to one of the axles of the carriage. The drums should be so proportioned in size, that the arm will make a definite number of revolutions at a given velocity, say half a revolution per second at twenty miles an hour. On any person seeing a train he would then, whether he was before it or behind it, know which way the train was going and at what velocity, or whether it stopped or was backing, the lamp turning with the sun when the train was going on its proper course, and against it when backing ; and each lamp should have a slide for a red glass to indicate danger, and this should always be shewn behind The opening or separating of the lights would be another criterion of its approach. These lamps were planned by the writer of this article, and are patented. To use them with advantage, no luggage or imperials should be on the roofs at night, but the luggage ought to be put in a proper luggage van, made for the purpose ; and if this were universally done in the day as well as the night, it would be much the best plan.

Prior to the line being finished, a host of little details will require to be attended to. When the number of policemen, gatemen, and switchmen are determined on, the necessary watch-boxes should be prepared. These should stand on a flat frame, fixed by screws to stakes driven into the ground; and on this frame the box should turn by means of a centre pivot, rollers being placed on the bottom of the box to facilitate its motion, so that the men can turn the open side

to leeward in bad weather; but unless the wood be very well seasoned, it would be better to cover the top with canvass before painting. These boxes should have a six-inch square of glass on each side and at the back. When the men are stationary, they should not be less than from six to eight feet square, with provision for a small stove. It may be necessary in some situations, and often advantageous in all, to build small houses for the switchmen, gatemen, and policemen along the line, and also for the overseers and platelayers. This would keep them near their duty, and enable them, in most cases, to get their meals with comfort; and a revenue would accrue to the company, from the rent, commensurate with the outlay.

Luggage shoots should be prepared before the opening of the line. These consist of an inch and a half plank, with two hooks at the top, about two feet in width, with sides rising two inches, and of such a length, that when it is hooked to the guard rails on the top of a coach standing alongside of the arrival stage, the end is on the stage, the shoot making an angle with the side of the coach of about 25 degrees. These shoots are hooked on to the coaches on which any luggage is carried, and the luggage is let run down them, being removed by a porter, who catches it without letting it arrive at the stage. They save much time.

Long and short ladders are also necessary; the short ones to get on and off at the arrival and departure stages. These should be more like stairs than ladders, and should have a hand rail. The long ladders are for getting up to the coach tops with luggage. They should be wide enough for at least two men to stand abreast; but a better plan is to have three steps like stairs, similar in shape to those for getting into high beds. They must be boxed in behind, and have a handle on each side, and being placed alongside the carriage, the luggage may thus be readily handed to the top. When the porter has delivered his load, he should move right or left on the ladder before he comes down, out

of the way of the next man, so as to keep a constant stream of men going up.

Point signals should be made in the following manner. The sliding rail, which forms the communication from one line of rails to the other, and which is moved by an eccentric, turned by a lever handle, should have, on the other side of the line, an iron rod from the rail, going into a box at its end with a pinion on it. This pinioned end of the rod turns a rack when the sliding rail is moved, which rack is contained in the box, and is fixed to a vertical rod, moveable in an upright post, similar to a lamp post, through the top of which, about four feet in height, the upper end of the rod comes out for about six inches, and is in this part made square. On this square part there is put a lamp by night, to shew a white light when the points are right, and a red one when they are wrong; so that whenever the sliding rail is moved, it of necessity turns the light round, and cannot fail to place the different colours in front of the line of rails to which the signal is meant to apply.

In the day time the lamp is removed from the square, which, however, is not necessary, and the same signal is made visible by two circular hoops covered with canvass, one being painted red and the other white, and one being fixed on the top of the other at right angles to it; or the hoops may be one inside the other, at the same height and at right angles, nothing more being necessary than that the signal should be such that when combined in this way, the sliding rail can never move without the signal also moving, which should shew white when the points are right, and red when they are wrong. These things, however, will never be properly correct till the engine itself is made to turn the points, which has often been tried, and is considered as having failed, but may certainly be done with ease and effect.

Trucks will be necessary to move luggage and parcels from the offices where they are received, to the carriages on which they are to be conveyed. A convenient form for these

will be a wicker basket, about 4 feet long, 3 feet broad, and 3 feet high, mounted on a wooden frame braced by iron, and running on two rollers about 10 inches in diameter, with their edges covered with leather. There should be four legs at each corner; each of these should stand about an inch from the ground, when the bottom of the basket is horizontal; and the frame should have at one end an iron handle, coning up at an angle of 45°, to a convenient height for the hand. Low platforms will often be required for the convenience of passengers and workmen getting along different parts of the station; and as these may have sometimes to cross the lines of rails, they should not be quite so high as the axle guards of the carriages; but if two small pits are sunk down in them about one foot wide at each rail, and covered with wooden doors turning on hinges, the carriages may pass through the platforms without any more delay than is required to throw open the two trap doors.

Great attention to ballasting is necessary, especially at the first opening of a railway; for, a long time afterwards, the road will require constant repair, and all the necessary materials will be continually passing on it. But these must give way and be got off for the passage of the legitimate traffic, except under very extraordinary cases. Hence every convenience should be furnished to the engineering department, in order to facilitate this object. In the goods' station also trucks of all kinds will be necessary, the size and description of which must be suited to the nature of the trade.

Luggage benches will also be required. These benches are about 20 inches high, 2 feet 6 inches wide, and are semicircular in shape, the radius of the inner circle being about 10 feet, and the outer, of course, 12 feet 6 inches. These prevent great confusion. They are placed with the diameter of the circle close to the luggage van or coach, and none but the porters should be allowed to go inside them. When the luggage comes down, it is put upon the circular bench,

and the passengers who stand round the outer circle have an opportunity of easily inspecting every thing as it lies. On pointing out their luggage, other porters standing outside lift it off the bench to make room for more.

Grease tubs will be required, with lids to them, and wooden knives to fill the boxes of the carriages with the grease. One man should be specially stationed to do this, and nobody else allowed to touch it; and he should be charged to keep the grease free from dust. The carriages suffer very much from this; the rapid motion, and the friction consequent on dust getting into the grease, bringing on rapid wear both of the axles and the boxes.

The grease which is put in at the grease-box, over the axles of the carriage, after having performed its duty, gradually falls out at the lower part of the box; and through the action of the wind, often falls on the inner part of the tire of the wheel. This should be carefully cleared away occasionally, and the boxes filled every journey; although instances have been known, of well made boxes and axles not requiring a fresh supply of grease, till the carriage had travelled 800 miles.

The best kind of grease for railway carriages is an object of no small importance, from the great loss incurred in the wear and tear of carriage axles. The two following compositions have been very strongly recommended for railway work; but we have had no opportunity of speaking of them from our own personal knowledge. The one is composed of Dantzig soap, boiled for half an hour in as much palm oil as it will dissolve, and a small quantity of water; and when the oil, soap, and water have combined, one quarter of the weight, of fine black lead powder should be added. The second composition is merely hogslard and fine black lead powder; but both in this and the preceding, the whole art consists in having the very best black lead, in the purest state in which it can be procured. This is best done by first pounding the black lead and then washing it; pouring off

the water, when all but the finest particles have settled to the bottom; and setting this water by till it deposits these particles, which alone are to be used. The first settlings may be again pounded when dry, and submitted to the same process as before. This has been found the only effectual method. Mr. Booth's patent grease is much used and highly spoken of. It is tolerably hard when cold, and melts with a moderate degree of heat, which is a desideratum; it is composed of common soda half-a-pound, and water 1 gallon; to which 3 lbs. of clean tallow, and 6 lbs. of palm oil are added, or instead of these, 10 lbs. of palm oil, or 8 lbs. of tallow. The mixture is then heated to 200° or 210° Fahrenheit, and well stirred till it cools down to 60° or 70° Fahrenheit, when it is ready for use. Soft unguents, such as oil or hogslard, only do for light weights; with heavy ones, a thicker composition must be used.

Lamp boxes, to carry the roof lamps in and out by, should be made exactly like a broad stool, long enough to carry ten lamps, holes being cut in the top, similar to the holes in the roofs of the coaches in which the lamps are put; and there should be an iron handle to the top of the box, so that it can be carried upright.

When a station happens to be in a high embankment, and there is much traffic, it will save a great deal of trouble if wooden shoots are placed from the top of the embankment to the bottom. On this the luggage can be slid down at once, a man receiving it at the bottom. By such a contrivance a great deal of time will be saved, which would otherwise be unprofitably expended in carrying it down stairs, and all that is practicable may be drawn up the same plane with a hook-rope.

At each station guages should be provided for the goods' waggons to regulate their height; and this must also be done in the passenger station, if luggage be carried on the coaches, which, however, is not by any means a desirable plan. These guages may be made of iron 3-4ths of an

inch round, and they may hang pendant from the roof, jointed, so as to swing to and fro when struck by the goods on the train starting; or they may be hung between two poles, a bell being attached to them, which gives warning of the danger. They should be shaped for each line like that part of the haunch of the arch of the lowest bridge which the train will have to go under, not like the centre of the arch, as is sometimes done ; and this shape will answer for both lines of rails, by merely reversing it in the hanging. In all cases they must be so placed as to ensure the whole train passing under them after receiving its loading.

Self-acting alarms, with gong-shaped bells standing upright and fixed about twelve feet high to a wall, should be supplied to each station, and they should be wound up by men stationed at them, who may also act as policemen. These alarms are for the purpose of giving notice to the station-people of the arrival of a train. Two minutes are sufficient time in ordinary cases, and, with active men, one would suffice, and proper regulations must be established to ensure this space of time. On the train arriving at the proper spot, the man stationed at the alarm pulls a trigger, which allows a weight to descend. This turns a wheel, and this wheel works a pinion, to which is attached an eccentric, which gives motion to the clapper from side to side, and the alarm is struck by the hammer in the usual way, the man stationed at it being at liberty to attend to any other business the instant he has pulled the string. A large station-bell is also useful to summon all the persons to their posts at unusual times, in order to receive any unexpected trains, and for many other reasons. A bell should also run from the station office at the out-stations, to summon one or more porters inside the office.

Moveable direction boards for many purposes will also conduce to the mutual accommodation of the passengers and those who convey them. These are fixed to an upright post about five feet in height, having a square stand

at the bottom. They may be used to point out the various offices, such as "Passengers' booking-office, first class," the same for the second class; "Parcels' booking office," "Horses' and Carriages' booking-office," "Office for engineers," "Cattle office," "Goods' office," "To refreshment room," "To waiting-room," and a variety of other uses. They save a deal of time spent in inquiries; and, what is of more consequence, they save the time spent in answering those inquiries. Five minutes before the train starts, a hand-bell should be sounded for the passengers to take their seats; boards of the above description may then be placed out in two or three conspicuous situations on the stage, with the words, "Take your seats" painted on them in good legible characters, to be removed when the train has gone. It is astonishing what time and trouble are saved by these contrivances.

A large red lamp by night should be fixed at the head of the arrival line, in the most conspicuous situation which can possibly be selected for it, so as to give certain warning to the engine-men of the exact spot beyond which they must not pass; and a green one at the point where they should slacken their speed, particularly at the first opening of the line; but it should be continued at all times, for new engine-men will constantly be taken into employ.

To rectify trifling accidents, each engine should carry two crowbars, one jack-screw capstan-headed, or, which is still better, the screw rose by a brass nut, having teeth round it, which are hove round by a pinion and lever; four wooden blocks to shorten the jackscrew with, and to be also used as fulcra; one towing chain and a short roller; and, when the accident is such as to disable the engine, there should be kept at each station a low strong waggon sufficient to carry the engine, with a tender attached, and the following tools, viz.

1 pair of legs, with a large lever or cathead piece.

1 treble and 1 double iron block, with gun-metal sheaves.

1 single iron snatch-block.

80 feet of 4-inch white rope, to give a 12-feet tackle.

2 luff-tackles, and two 40-feet falls of $2\frac{1}{2}$-inch white rope.

3 spare blocks as above, and a spare fall.

4 ropes for the head of the sheer legs, 30 feet each, of 3-inch white rope.

1 winch on a frame, and 1 ton of kentledge; the winch should also fix on the sheer legs, and likewise to the waggon.

2 crowbars 9 feet long, and two of 5 feet.

2 capstan-headed or wheel and pinion-headed jack-screws, working in brasses, with an 18-inch rise, and two blocks to shorten them.

4 sets of fulcra, one for each lever.

1 pair of chain slings to lift the engine, with a hook and a ring at each end; this may also be used as a drag-chain and as a pendant.

2 other chains, sufficiently long, when hooked together, to reach the bottom of the highest embankment with the greatest slope on the district.

12 short piles for driving into the ground to fix the head-ropes of the sheers to, attaching chains, &c.; 1 large maul for driving in the piles, 1 sledge hammer, 1 hand hammer, 1 nail, screw, and nut box, 1 axe, 1 saw, 2 screw-drivers, 1 screw-winch for nuts, 1 mallet, 3 chisels, 2 spades, 1 pick, 4 planks and 4 rollers, to get the engine up an embankment.

Several wedges and some spare wood.

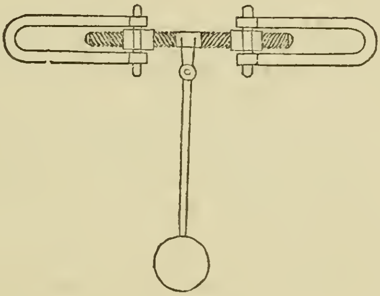
The most convenient thing in practice is to have a strong wooden inclined plane, say about 4 to 1, with supports about every three feet, by which, and the winch fixed at the farther end of the waggon, the engine may be heaved up into the waggon, and, by placing and wedging the waggon across the railway, the winch can heave the engine up an embankment. These things should be kept constantly loaded and ready to start at a moment's notice, with at least one man, accustomed to the kind of work, as a leader.

A good means of preventing accidents would be, to have the engine-man in the front of the engine. If any thing could ensure care, this would, the generality of engine-men being quite foolhardy ; a defect which will never be remedied till we have a distinct class of men educated and brought up for engine-men from their youth, to whom should be given such a salary as would bring in young men of respectability. The present class are working mechanics, and are too little interested to be as careful as is requisite ; and in addition to this, they get more wages than with propriety they can spend with their family, which leads to a habit of drinking, and has occasioned loss of life in several instances. And when we look at the value of the property at risk, without taking into account the loss of life, it is not too much for the proprietors of railroads to demand, that all engine-men should go through a public examination as to their qualifications, before they are entrusted with such a weighty charge. With a train of ten carriages, say, five of the first class and five of the second, we have the engine, value L.1500, five first-class carriages at L.400 each, making L.2000, and five of the second class at L.130, making L.650, or a total of L.4650, entrusted to a man at weekly wages, and who knows, if he has the bad luck to be turned away by one railway company, he can always get employed by another.

When spare lines of rails are laid in, for instance, at the principal station, there must be proper wooden stops fitted and fastened at the ends of the rails to prevent the carriage from running off; and the same thing will be required at each turnplate at the ends of the rails, and also in those next the stage. Several loose stops, generally called hubs, should always be kept at hand to check the wheels of the engine and carriages ; they should have one end cut away from below to form a handle, and by its being cut away from below, the hand can always be readily got under it in any position. A stand will also be required for the coupling-

bars to hang on, so as to be always at hand. Experience has shewn that those coupling-bars patented by Mr. Booth are perfectly adapted for their intended use ; they consist of two links about ten inches in length, which go over the hook in the drawbars of the two adjacent carriages, and they are connected with a double-ended screw, by which they can be drawn nearer together or put farther apart The screw is kept in its place by a lever and weight attached to it, which hangs down below the screw vertically, and preserves it in its place at each turn, if not altered by hand. In practice the screws should be turned two or three times round after the buffers touch, to draw the carriage well

Fig. 38.



together. This is found to induce much greater steadiness and smoothness of motion at high speed than is the case when the buffers are not close.

When turnplates are used in a station, they occasion large bays to be cut circularly out of the arrival and departure stages, which are very inconvenient. The best way of remedying this is, either to have a wooden platform the size of the bay, to draw in and out from under the floor of the stage ; or it may be done by a railed moveable wooden platform, going on friction rollers on the top of the stage ; or it might be still better remedied by having the floor of the booking-offices to rise a couple of steps, and let the part

of the floor of the platform where the bay is, be of wood, and slide in under the booking-office floor.

Turnplates are very troublesome things, and in general require constant attention. The best way to help this is, to have them well made at first. Their diameter will be determined by the length of the engines belonging to the line, or likely to come on it from other railways; and their frames should have a stout cross underneath, on which should be cast the circular rail for the rollers to run on. This is often cast on the outer frame, but the above method is an improvement. The rollers should be conical, the rim on which they run being made in the same shape; the rollers, at least eight in number, and twelve inches in diameter, should be made not less than four inches wide, and their rail from two to three inches inside the frame, (Plate CCCCXXVIII. fig. 1), so that no dust falling down between the table and the frame, can lodge on the rollers or their rail. Where turnplates are obliged to be used on the main line, there should be a secure lock in addition to the usual catches, to ensure their being firmly fixed in the required position.

The centre pedestal may be of cast iron, with a hole bored out in it three inches in diameter and five inches deep, at the bottom of which a brass stop must be put, on which the pivot works. The rim, plate, and centre hole, should all be turned in a lathe, so that they are not only each true in themselves, but true one to the other. The rails on them should be of wrought iron, three inches thick and three broad, bolted to the principal arms with three-quarter inch screw bolts, with countersunk heads flush with the rails; the ends should be rounded, and have a bearing on the frame The catch should fall into a hole, half in the table and half in the frame, so as to steady the table when any thing comes on it. It should be fixed to the table, not the frame, and should form a bent lever, hand high, and curved out sufficiently to clear the buffers of any vehicle which may come upon the turnplate. The mode of using it will be, first to lift it up, then the

handle forms a lever, by which the plate may be turned round, and when it comes near the hole, it may slide on the plate by lowering the hand, till, on coming to the right part, it falls in of itself. They should have a hub to stop the wheels when the carriage is in its right place, with a self-acting catch to retain it there, which should be opened by a man's foot, otherwise much time will be lost in pushing the carriage about.

Directors of railways out of very large towns, should always bear in mind, that those upon which the public find most accommodation and attention to their wants, will, in the long run, carry away all the pleasure traffic; and there are many things yet requisite in this respect. We may instance the regulations (April 1838) for the London and Birmingham railway, that no person can come into the station to see their friends off by the train. This is positively inhuman, and by what process such an insult to the public can have been allowed to come into operation, we know not. Infancy and age, sickness and imbecility, are alike disregarded; and any one who wishes to see husband or wife, child or friend, to the moment of their departure, has no means of doing so but by taking a ticket to the next station on the line. When a thing is so palpable a monopoly as a railway will in general be, and as that railway in particular is, care should be taken not to shew it. On the same railway the charge for dogs is monstrous, namely, ten shillings, which has been exacted even for a lady's lap-dog, carried in a muff. Such regulations as these will drive all those from the railway who are not obliged to travel on absolute business; and with an expenditure of five or six millions, (and another line now in the course of construction will most probably exceed the highest of these sums), every thing that can be done to procure traffic will be necessary, instead of throwing it away. Dogs are not so often required to be carried, and when they are, should be taken at a reasonable rate, and in proper boxes made for the purpose, not locked up

under the seats of the second-class carriages, at the risk of being stifled; and when the owner goes at the same time, no charge whatever should be made.

If a reasonable time for refreshments cannot be allowed, and if the necessary viands for breakfast and luncheon are not provided at the stations, a refreshment carriage should be fitted up for those who choose to take any, which might very simply be done with a stage in sliding parts to lead to it, or the carriages might be made high enough to walk in, and have a communication from one end to the other of the train, as is done on some of the American railways, the passengers sitting along the sides. This would enable every accommodation to be afforded, including portable water-closets. These American carriages are often 60 feet in length, supported by friction rollers on two four-wheeled trucks, to which they are fixed by central pivots, allowing the wheels to accommodate themselves to the curves; and they are also well warmed with stoves. A smoking carriage might also be fitted up, as this habit has become almost a necessary of life with many people; it should be placed last in the train, except horse boxes and empty private carriages, and no platform should communicate with it, nor any connexion exist with the other carriages.

In Plate CCCCXXV. fig. 4, we have given a plan of a carriage of this kind, which might either have an attendant placed in it by the railway company, or be farmed out to any person to hire. Here (*a*) would be the compartment for the attendant, who would sell cigars, lemonade, ginger beer, &c.; the sides (*b*) (*b*) of this division of the carriage might be fitted up with rows of shelves to hold the necessary stock. The circular front would admit of considerable ornamented decorations, such as gilt pillars, French polished wood, inlaid work, &c.; from a little lower than breast high, it should be open to the top, and where the open part commences, a small shelf should run round, serving the purpose of a counter. The seats (*c*) (*c*) would be best placed lengthways in the

carriage, as in omnibuses, and as they need not be more than sixteen inches wide, there would remain three feet four inches central space, which would be amply sufficient to allow every one to pass from one end to the other. The necessary ventilation might be had both at the sides and roof, the door being either placed behind, or if at the side, a hinged seat would be necessary to be turned back on getting either in or out.

What we look to in recommending these accommodations is, the number of persons who would take advantage of them, purely for recreation; and we are convinced that no inconsiderable sum of money would be turned into the cashier's hands at the year's end. Many other conveniences might also be contrived on a similar plan. Carriages might also be reserved entirely for ladies, which would form no inconsiderable accommodation in many instances; also, for out-stations, a first, second, and third-class coach may be made in one carriage. Sick carriages would be another great convenience. These might be fitted up in compartments holding two persons each, that is to say, the invalid and his attendant, with a communication to a compartment containing a portable self-acting water-closet. How many persons under the affliction of severe illness would gladly pay double and triple the usual fares for such accommodations as these, whilst the cost to the railway company would be trifling in the first outlay, and amply repaid again with grateful thanks?

By the use of the sliding stage along the carriages, and, still better, by the before described arrangements in America, all the passengers might be accommodated with access to an apartment containing a portable water-closet, the gentlemen being on the one side, and the ladies on the other, and a certain sum being paid for the accommodation, say sixpence, on the fare of each person. No complaint could ever be made of this small charge, and it would amply repay the outlay. Having a means of communication from one carriage to another, is a great desideratum in many respects; and

as it is perfectly practicable, it is to be hoped that the march of improvement will not cease till it is obtained. In road travelling, a passenger suddenly taken ill, or from any other cause, has nothing to do but to put his head out of the coach window and make his wants known; the coach can be stopped, and he can receive the necessary assistance. But how different is the case in railway travelling? There, unless he has by accident a seat just under the guard, he might exert his voice in vain, and could by no possibility receive the least help if he was dying; in fact, the more he wanted it, the less able would he be to endeavonr to obtain it.

In Plate CCCCXXV, fig. 3, we have given a plan of an invalid carriage, capable of containing four invalids and their four attendants. (*a*, *a*) are the seats for the passengers, one on each side of the first and second bodies of the carriage being for the invalid, and the opposite one, lengthways of the carriage, being for the attendantt. When the invalid wishes for the use of the closet, he comes out by the door (*b*) into the middle part of the coach (*d*), which is a gallery with a raised roof, as in fig. 2. There are three portable water-closets (*c*) in this carriage, or the middle one, if thought more desirable, may be merely an urinal; the centre one, to whatever purpose it may be converted, is arrived at from the gallery by the door (*e*), and the right and left-hand closets by the doors (*fg*) (*fg*) respectively. The ventilation here would be very perfect, and no inconvenience whatever could arise to any one of the passengers. An attendant belonging to the railway company could attend on all the passengers remaining in the gallery (*d*) till his assistance was required, for which purpose a bell might be hung with pulls in each compartment. By this arrangement double the number of invalids could in each case be accommodated with a passage.

It may be thought that the number of travelling invalids would be so few as hardly to pay the expense of such carriages as these. Setting aside the want of humanity in such

an argument, the public have a right to demand some kind of accommodation in this respect, railways having driven from the roads those long established conveyances in which the passengers could be allowed to stop and administer to the wants of nature when imperative, and replaced them by another system, which, great as are its advantages, is certainly in this instance a deprivation, and liable to be a cause of much bodily suffering. Besides, it is not the number of invalids who are obliged to travel, but the number who would travel, both for business, health, and pleasure, if they could have the means of doing so with safety and convenience. How many would be happy to avail themselves of such a mode of conveyance, at almost any price; whilst for the poorer sort of passengers a cheaper carriage might be constructed, which would answer the desired end at very little more expense than the usual second-class coach.

It would be well worth while to try towing the trains by a rope or chain sufficiently long to enable the brakesman to put on the brakes and stop the train if any accident happened to the engine. This is often done at particular parts of a line, and if extended as above, would reduce all danger upon a railway to a most insignificant minimum. It might be tried in the first instance with a train of waggons. A look-out man on the front of the engine with a small telescope, would still farther lessen even the small remaining chance of danger; but in the way engines are now generally made, the engine-man is behind them. A very small object would be discovered at a considerable distance by the above means; it would also be seen when points were wrong; and at any rate no such thing could happen as a rail being left out and no one being aware of it from the train till the engine was thrown off the line, a circumstance that has taken place in numerous instances.

A light advice carriage might also be advantageously attached to each train, with no body, but only a framing to admit two men to stand, having wheels in which the weight

is decreased in the greatest possible degree, one pair of which should be worked by a wheel and pinion, and a tread-mill motion. Two men would run such a carriage as this at the rate of 20 miles an hour, and by its means assistance might be procured in the case of an accident from the next station in a very short time. The working wheels, if 3 feet in diameter, should make about 190 revolutions per minute; and the carriage complete, should not weigh more than 2 cwt., so that the two men could lift it off the line out of the road of any thing that it might by any possibility meet; but if lifted at first before starting on to the proper line for travelling on, in the direction it would have to go, there would be no chance of anything being in its way, except under very extraordinary circumstances.

In case of an axle breaking, particularly with four-wheeled engines, proper supports with flanged rollers should be fixed a small distance above the rail, on which the engine should come directly the axle went. Numbers of crank axles have broken from bad welding and other causes. Perhaps the best way to prevent this, is in all cases to have the entire crank and axle cut out of a solid piece of iron, which can be, and has often been done, or to do away with them altogether, and have straight axles, which can be accomplished.

Care should be taken to order engines in time, as the best makers are now (1839) so full of work, that it is with difficulty they can execute their orders, and some are employed for the next three years. Mr. Stephenson's engines are now made with two horizontal cylinders 13 inches in diameter, fitted with single slide valves and metallic spring pistons; and the length of the stroke is from 16 to 18 inches. The cylindrical portion of the boiler is 8 feet in length, and $3\frac{1}{2}$ feet in diameter, being made of malleable iron plates $\frac{5}{16}$ths of an inch in thickness. The fire-box is of copper, 2 feet 6 inches in length, by 3 feet 4 inches in width; and the depth from the crown to the upper side of the fire-bars is 3 feet 3 inches. They have a clear water space of 3 inches on all sides of the

fire-box, except where the door is, and on that side next to the cylindrical portion of the boiler; in this latter the clear space is 4 inches. The extreme width of the fire-box casing should not exceed 3 feet 11½ inches, and the plates which form the roof and sides of the fire-box should be $\frac{7}{16}$ths of an inch in thickness, excepting the tube plate, which is ¾ths of an inch thick.

The roof plates are strengthened by means of four wrought iron bars riveted to the upper side, and the sides supported by copper stay-bolts, tapped and riveted. The hole for the fire door is of an oval shape, and formed by setting the plates together, so as to approach within 1½ inches of each other, a copper ring of that thickness is then inserted, with half inch holes drilled in it, two inches asunder, and then closed by sound copper rivets. The number of tubes run from 80 to 130; a very good number is 115 of 1⅝ inches diameter outside, and not less than 1 inch asunder, made of best tough rolled brass, with a lap joint; the edges of the sheet being first properly chamfered, and the solder applied inside the thickness of the tube. The brass is No. 15 wire guage, and should be made truly cylindrical by drawing through a die; the holes in the back plate of the fire box for receiving the tubes, are drilled truly cylindrical, without countersink, and the tubes inserted in the usual manner by steel hoops.

The diameter of the first and third pair of wheels is 3 feet 6 inches, and that of the driving pair 5 feet, or 5 feet 6 inches; the naves are of cast iron, and the arms and rim of malleable iron, hooped with a tire 1½ inches in thickness, and 5 inches in width, inclusive of the flange, which should rise 1 inch above the coned portion of the tire. The combined form of flange and cone of the tire should be made from a template, to be furnished by the company, and fitted with reference to the curves of the railway in question. The driving wheels may be without flanges.

The crank axle is made of the best Backbarrow iron, 5½ inches in diameter at the crank pins, 4½ inches in diameter

in the middle between the cranks, 5 inches in diameter alongside the nave at the inner bearing, $4\frac{3}{4}$ inches in diameter inside the two cranks, and $3\frac{1}{4}$ inches in diameter at the outside bearings. The whole of the angles are well rounded off, according to a pattern furnished. The axles of each pair of small wheels are $3\frac{3}{4}$ inches diameter, with three-inch bearings; and the whole of the bearings of the axles, and the eyes of the working gear, are case-hardened.

The crank axle is supported by four inside longitudinal wrought iron frames, with brass bearings inserted; and these frames are attached to the casing of the fire box at one end, and to the smoke box at the other, for the purpose of firmly staying the cylinder beds. The outside or principal framing, is made of well-seasoned ash plank, 3 inches thick, and 7 inches deep, plated on both sides with sound Lowmoor plates, or others of equal quality, a quarter of an inch thick. The under side of this frame is 3 feet from the surface of the rails; one feeding pump is worked by each cylinder; and the working barrels and valve seats are of the best tough brass, with a clear circular water way throughout, not less than two inches in diameter. The suction pipe is constructed with double ball and socket piece, to avoid the necessity of leather or India rubber pipe for communicating with the water-tank.

The eccentrics are made to shift on the crank axle in the manner hitherto generally adopted, or fixed on the axle, provided the method of changing the gear, and the other conditions requisite for placing the slide valve correctly, where the engine travels backwards or forward, be approved of by the company's engineer. For details of arrangement, description of workmanship, and general fittings, such as working gear, safety valves, guage cocks, water gages, buffers, splashers, safety guards, wire chimney cap, wood sheathing to the boiler, and all other similar appendages for putting the engine in complete working order, reference should be made to some specific engine, as a pattern, in which these

parts are of an approved constitution. Deviations from any of these points might at all times be made, if approved off by the company's engineer. Some engines have no hand gear, yet work very well; some are oiled by syphon wicks, others by cocks and tubes; some have a steam pipe into their tender to warm the water, others not; in fact, each maker has his own peculiarities.

It is not even yet agreed upon, whether it is best to have the framing of the engine inside the wheels or outside. When it is inside, the bearing weight is on a much shorter length of axle, and engines made this way, have hardly ever broke a crank axle; when it is outside, there are four bearings, instead of two, by means of stays, and these, in some cases, are increased to six. The outside framing has also this advantage, that the engine-man can always get to inspect the machinery, and supply it with oil, if necessary, whilst the engine is going on. The framing of the tender should be of ash, the tank of wrought iron plates of 1-8th of an inch thick, and to be capable of containing 700 gallons of water, and furnished with the necessary means for communicating with the ball and socket suction pipes before described. The wheels and axles should be precisely similar to the small wheels described for the engine, and the tender supported on springs and furnished with a long transverse spring at each end for drawing by, together with a brake and buffers; also a box of tools, containing a complete set of spanners suited to the different-sized screw bolts and nuts throughout the engine, with cold chissels, hammers, and duplicates of such bolts and nuts, as require to be moved in the general course of working. The engines and tenders ought all to be subject to the inspection of the company's engineer; a trial of not less than 1000 miles should, in every case, be stipulated for, and the company should be allowed to test the boiler up to 120 lbs. on the square inch.

The following are the engines in use on the London and Birmingham railway, and which were made by Mr. Bury of

Liverpool. The description here given applies to both the passenger and goods' engines, except when otherwise stated.

The two cylinders are to have an 18-inch stroke, those of the passenger engines being 12 inches, and the goods' engines 13 inches in diameter, with single slide valves, brass spring pistons, and cast iron packing; the cover of each cylinder having one oil cup. The boilers are made of the best Yorkshire plates, either Bowling or Lowmoor. The fire-boxes are of the same material, and are welded so as not to have the rivets or lap exposed immediately to the action of the fire. They are 3-8ths of an inch thick, the back plates half an inch, the outside of the fire-box and the backplate 3-8ths of an inch, and the rest of the boiler $\frac{5}{16}$ths of an inch. Full-sized drawings are furnished to shew how the plates are to be worked; the plate for the tubes at the smoke-box end is half an inch thick, and a lead plug, 5-8ths of an inch in diameter, is riveted in the crown of the fire-box.

The tubes are two inches in diameter inside, and are secured with steel hoops at the fire-box end, and iron hoops at the chimney end. These hoops are made to a given guage; and the tubes are of the best rolled brass, No. 14 wire guage thick; the arrangement as well as the exact size of the tubes being regulated by a template.

The engines have four wheels; those for the passengers are $5\frac{1}{2}$ and 4 feet in diameter, and those for the goods are each pair 5 feet in diameter. Each wheel has a cast iron centre; and the spokes are of wrought iron, accurately fitted into the nave. The tire consists of two thicknesses, the inner being 3-4ths of an inch when finished, of the best Staffordshire iron, well secured to the end of the spokes by riveting, the ends of the spokes having been previously turned in their exact position. The outside tire is made of the very best Bowling or Lowmoor iron $1\frac{5}{8}$ths inches thick when finished. When the outside of the inner tire has been well riveted to the spokes it is turned; and the inside of the outer tire

having been accurately bored, so as to secure a perfect fit, it is then shrunk on, and the outside turned and finished. The naves are bored out, and the axles turned to fit; they are secured on by two steel keys, one inch square, at right angles with each other. The goods' engine wheels are connected on the outside by a rod, with a ball pin at one end, and a parallel pin at the other. These engines have also a damper to their blast pipe.

The crank axles are made from Backbarrow iron, cut out of solid blocks, and finished according to full-sized drawings. The straight axles are made of the very best scrap iron. The framing of the engine is of wrought iron accurately fitted. There is one pump attached to each cross-head, and made of good tough brass, the suction pieces being connected by Macintosh hose pipes, with screw coupling joints next the engine. The eccentrics are fixed on the crank axles in the mode shewn by drawings. The steam and exhausting pipes are of copper, No. 12 wire guage in thickness. When these engines are made by other persons, templates and full-sized working drawings are given out, from which no deviation whatever is allowed without Mr. Bury's approbation, so as to secure all parts of the engines matching each other.

The top of the fire-box has a copper cover, No. 16 wire guage thick, secured to the wooden covering on the lower part of the fire-box and body of the boiler, by screws two inches apart. The wooden covering on the fire-box is finished to $\frac{5}{8}$ $\frac{1}{16}$ thick, and is made fast to the boiler by two hoops; and round the fire door it is lined with thin sheet iron under the hoops; the sheets being 6 feet long, and 2 feet 3 inches broad, with a hole cut out for the furnace, and secured at the ends by screw nails 2 inches apart, to prevent the fire from burning the wood casing on the boiler. The casing on the barrel of the boiler is secured by four hoops, with a strip of brass under the fore-end hoop, about $2\frac{1}{2}$ inches in breadth, to cover the ends of the lining and the rivet heads at the junction of the barrel of the boiler, and the smoke-

box. The boiler is wrapped in at least three thicknesses of flannel all over.

The lagging on the boiler is put together with iron feathers $\frac{5}{8}$ by $\frac{1}{8}$; the boiler is covered over the lagging with thin sheet lead, about $3\frac{1}{2}$ feet broad along the top of the barrel. The smoke-box is No. 7 wire guage thick, and the chimney is No. 13 wire guage. The cover on the lock-up safety valve is of brass, secured to the boiler; there is a brass frame round the door of the smoke-box, and a brass handle to the small door in the middle of the large one.

All the pins of the joints are of steel, and hardened when practicable, but if not, they are steeled and hardened, and the working parts of the engine, which are of iron, are case-hardened. In making the boilers, the sharp edges of the rivet holes are taken off on both sides, and the rivets and rivet heads made to correspond. The engines are furnished with a wooden guard, and two leather buffers stuffed with cotton flock; and there are a draw-bar, draw-pin, and loop in the centre of the wooden guard, to connect them to the tender. They have three water guage cocks, and a glass water guage, with a lamp stand; also a whistle, and a number plate on each side of the boiler; and they are furnished with a complete set of screw-keys.

All the screws in all the engines correspond, for which purpose, either master taps, or sets of stocks and dies, at the option of other makers, are furnished them by Mr. Bury. They receive two coats of paint, and are finished with two coats of the best varnish. They are guaranteed for one month, or 1000 miles, during which trial, no other work is allowed but the tightening of cotters, and the very best workmanship and materials that can be produced, are in all cases rigidly insisted on.

The framing of the tenders is of well-seasoned oak, or ash timber, thoroughly secured with iron knees and bolts, having an iron box, No. 7 wire guage thick, underneath, to carry the coke, which box is secured to the wooden frame.

The tank contains 700 gallons of water. The wheels are of cast-iron, turned to receive a tire of either Bowling or Lowmoor iron, bored out to secure a perfect fit, and finished to $1\frac{1}{4}$ inches thick. The axles are $3\frac{1}{4}$ inches in thickness, of the best hammered scrap iron; and the journals are $2\frac{1}{4}$ inches in diameter, case-hardened, with brass bushes and oil box.

The steadiment for the axles consists of two plates, one outside, and the other inside the framing; both of them being bolted through the framing, and secured together below, by a piece of iron between the plates for steadying the axle bushes. These are made completely parallel, and the bushes fitted into these so as to move up and down, but in no other direction. The tenders have buffers, a spring to which the load is attached, and also four springs by which they are supported, one over each oil box.

The tank is No. 10 wire guage thick, having two brass cocks or valves, and rod handles with bushes for the top of the rods; also two copper pipes, $1\frac{3}{4}$ inches in diameter, for carrying water from the tender to the engine. The tender frame and tank have two coats of paint inside and out, and two coats of varnish. They are fitted up with a brake, and furnished with a complete tool box; a wire sieve in the main hole of the tank to prevent dirt or water from getting into the tank; and two Macintosh hose pipes, one to each suction piece, with the necessary connexion to attach them to the engine.

When water requires to be pumped from the tender into the boiler of the engine, previous to the starting of the train, it is the usual practice to run the engine backwards and forwards for a short distance, in order to work the force pumps. This increases the wear and tear both of the engine and the road, besides inducing a liability in a crowded station of running foul of something, if great care be not taken. The following contrivance will obviate the necessity of this inconvenient method of filling the boiler. A square pit should be sunk in some convenient part of the line, selected with re-

ference to its intended use. This pit should be large enough to admit a pair of three-feet wheels fixed on an axle similar to the carriage wheels. There should be no flanges, and a part of the circumference of these wheels should come up through the rails, which must be cut so as to admit them, additional chairs being put in to support the ends of the rails. This part of the circumference of the wheels thus becomes a part of the railway, the wheels being made to lock at pleasure; but when the engine requires to pump water into the boiler, it must be brought with its driving wheels directly on those in the pit, and these latter being then unlocked, the steam is let gradually on, and the pumps worked as long as is found necessary to fill the boiler, without the engine advancing from the exact spot in which it was first placed, the only effect produced by the driving wheels of the engine, being to turn round the wheels fixed in the pit. When the boiler is filled, the pit wheels are locked, and the engine proceeds to the performance of her assigned duty. How much more advantageous this mode of filling the boiler is, will be readily seen, particularly when it is remembered that if engine-men are not looked well after, they will oil the driving wheels and the rails when in the engine-house, and then letting on the steam, fill their boiler by means of the wheels slipping round on the rails. We have often seen this carried to such an extent, that streams of sparks have been struck out by the attrition. When no better plan can be obtained, the engine should have one end lifted by screw-jacks, till the driving wheels are off the rails, and the steam may then be let on without any damage being done.

The Caliban engine, made by Sharp, Roberts, and Company, of Manchester, drew 80 tons up an inclination of 1 in 180, on the Grand Junction Railway, for $3\frac{1}{4}$ miles, at $13\frac{1}{4}$ miles per hour, at a steam pressure of 50 lbs. per square inch, and with a consumption of coke of 480 lbs. The average of 14 trips of three quarters of a mile each, up 1 in 90, from Euston Square to Camden Town, on the London and Bir-

mingham railway, with the great engine made by Robert Stephenson and Company to work the trains up the inclination till the fixed engine was ready, amounted to 15 miles an hour, with 70 tons, viz. 14 carriages and 148 passengers, at a steam pressure of 50 lbs. per square inch. The average of 12 trips of $24\frac{3}{4}$ miles, up 1 in 440, on the Grand Junction Railway, with six engines, three made by Robert Stephenson and Company, and three by Sharp, Roberts, and Company, was $23\frac{3}{4}$ miles per hour, with a weight of 58 tons. The coke consumed was 864 lbs., and the steam power 48 lbs. per square inch; this coke, however, was very bad. The average of 14 trips of 23 miles, up 1 in 440, on the London and Birmingham line, with No. 16 engine, built by Mr. Hawthorn of Newcastle, was 22 miles an hour, with a gross weight, including the tender, of 70 tons. The coke consumed was 486 lbs., and the steam pressure 48. The engine No. 7, on the London and Birmingham line, built by Mr. Bury of Liverpool, went 10 miles in ten minutes, 3d October 1838, with only one cylinder working, namely, from Hampton to Birmingham, being for $4\frac{1}{3}$ miles, up 1 in 660, $3\frac{1}{3}$ miles, up 1 in 1370; the rest of the way was level, and the time included the getting up and slacking down the speed.

Whilst such machines as these can be turned out of hand, we may rest satisfied, although considerable improvements will doubtless be yet made, great difference of opinion still existing respecting the proper size of the driving wheels, which may either be made larger to give an increased speed, or keeping the speed the same, the piston may move with less velocity, either of which is a desideratum. The crank axle may also be done away with, as Dr. Church has exemplified in his engine, or by other means, or it may be cut out of solid iron. At present, too, the steam whistle, which can be heard several miles in a still day, is only made use of to warn persons of the time when the engine is approaching them. How much better would it be to have two of these with totally distinct sounds, one to be used on the arrival

line, and the other on the departure line? Each would then not only perform its present office as an alarm, but would form the most complete fog and night signal that could be desired, and would at all times, in the densest fog or the darkest night, give perfect notice whenever two engines approached each other, on which line each was travelling, and thus prevent almost the possibility of a collision.

There has so seldom been an instance of a locomotive engine boiler bursting, that it is perhaps hardly necessary to advert to such an accident. We know only of two amongst the tubular boilers. One happened lately on the Liverpool and Manchester Railway, apparently from the boiler being used till the rivets got so worn, that they were weaker than the tubes. The fire-box end of the boiler was blown out, and the above is the only way of accounting for it, as tubes must always bear a steam of 50 lbs. on the square inch. Of course when new, they bear considerably more, and their form gives every advantage to their strength, the pressure on them being inwards, whilst on the boiler it is outwards. It is also known that the safety valve was held down. The second instance occurred on the Brussels railroad. In this case, the lock-up safety valve was found to be loaded to 105 lbs. upon the square inch; and it had also been screwed down more on one side than on the other. These valves are held down by a series of elliptical springs, which move on a guide rod passing through their centres. When they are not screwed down equally on both sides, their position becomes diagonal, and they jamb on the guide road instead of working easily, as they do when rightly managed. Safety, in all the usual cases, is insured by having a fusible plug on the top of the fire-box, composed of four parts lead and one part tin. This will melt before any danger can arise, and the steam will rush into the furnace. The late American experiments on this head may be consulted with advantage; but the mystery has not yet been unravelled. We have had an open vat burst in Meux's brewery; and in two instances boilers have been

suffered to get quite cold. The man-hole has then been opened, and a person has gone inside, but soon afterwards, in each instance, upon their introducing a lighted candle, explosions took place, and they were in both cases killed. Gas generated by boilers getting red hot, and absorbing the oxygen, has been supposed to be a leading cause; this, however, is exceedingly doubtful. If such be the case, it might be well to try protecting them by means of another metal. It would also be a good thing to rotate the safety valve, which is locked up from the engine-man, by machinery, to prevent any improper adhesion, and by using a mercurial steam guage, nearly all blowing-off at the safety valve might be avoided, which now often amounts to one-fourth of the generated steam. The boiler tubes, as now made, are capable of running 30,000 miles. The want of adhesion so much talked of, is found to be nonsense, and if there had been any, it would only be necessary, as the writer of this article suggested several years ago, to connect a galvanic magnet with one or more of the axles, to act on the rails, by which means, with the addition of only a few pounds, an adhesion equivalent to the weight of two tons could be produced at each axle, being capable also of acting or not at a moment's notice. But there is always found to be sufficient adhesion, except sometimes in foggy weather, at first starting; when once in motion, the train acts as a fly-wheel. We have no hesitation in saying, that electro-magnetism will at no distant day compete with steam as a motive power, and successfully.

We are yet, however, very ignorant not only of the powers but even of the nature of steam. No one can satisfactorily prove whether it is a mechanical division of water, or a chemical decomposition. The currents which take place in water whilst it is heating, and which are reversed when it cools, are not yet taken sufficient advantage of, and there are many other facts which require examination. It is well known, that if we put on our bare hand, an iron kettle of

water boiling rapidly we feel no sensation of heat, but the moment the ebulition ceases, we feel a gradually increasing warmth, which is greatest at the edge of the bottom. When the bottom, well cleaned, is placed almost in contact with the bulb of a thermometer, it will only raise it 8° or 10° in thirty seconds, or about 40° in five or six minutes, although the water, at the expiration of that time, will be at 90° higher. With an earthenware pot, the difference is very great, the thermometer rising 100° in thirty seconds, instead of 8° or 10°. A drop of water placed in a metal vessel, at a white heat, is very slowly converted into steam, whilst at a lower temperature its conversion is so rapid, as almost to resemble an explosion. At the high temperature, it will spin round, and will take nearly a minute to evaporate, during which time, if it be turned into the hand, it will barely feel warm.

The experiments made by the committee of the Franklin Institute of Pennsylvannia, are well worth consulting on these subjects. It is there shown, that a drop of water on polished copper, at the temperature of 445°, took 210 seconds before it was converted into vapour. It was evaporated in the smallest time, at a temperature of 292°, at which it took three seconds. But when the copper, instead of being highly polished, was highly oxidated, the temperature of maximum evaporation was at 348°, and the time required to convert the drop into steam only one-fourth of a second, or as 12 to 1; whilst in iron the temperature suffered but little variation, whatever was the condition of the metal, except it was very highly oxidated, the iron having its highest evaporating points in this case about 35° above copper in the same condition. The time varied nearly in the ratio of the conducting power of the metals, or about 2½ to 1, the copper requiring the least.

At 20° to 40° above the point of maximum vaporisation, there is a perfect repulsion between the drop of water and the heated metal, the former rotating in all directions, with-

out wetting the metal. When larger quantities of water were used, the point of maximum vaporisation was much higher; which renders it evident that locomotive engines have yet to be considerably altered, before they can work at the greatest advantage. The same experiments shew, that water injected, either hot or cold, into an engine boiler, heated to bright redness, produced no hydrogen, but that the resulting gas was nothing more than atmospherical air, deprived by the heated metal of more or less of its oxygen; that is to say, nitrogen more or less pure, according to the quantity of oxygen which has been absorbed.

The nature of the most advantageous alloys for the fusible plugs of locomotive or other high-pressure boilers, has been carefully examined by the same committee, and the table on the following page is deduced from their observations, the stationary point being that of congelation.

The proportions are by weight throughout. The stationary points are not given for the ten latter alloys, but the decrease in temperature by which they became "hard solid," on the surface we presume, was as follows, viz. 25°, 24°, $20\frac{1}{2}$°, $22\frac{1}{2}$°, $30\frac{1}{2}$°, $32\frac{1}{2}$°, $48\frac{1}{2}$°, $50\frac{1}{2}$°, $49\frac{1}{2}$°, 46°. The arrangement of the table is in the order in which the alloy begins to solidify. A correct knowledge of the nature and properties of steam is of such importance at the present day, that the matter ought to be taken up by government. Private individuals are not able to incur the expense necessary in conducting a complete course of the experiments which are required to fully develope such an intricate and voluminous subject.

The practice of putting two engines to a train is not considered so good as dividing the train into two, and putting one engine to each. Whatever may be the objections to the latter plan, those who argue in this way assert that no two engines will have their wheels mathematically accurate as to size, and if they had, still their rate of working, depending as it does on so many elements, would always prevent

Table of the Fusing Points of Alloys for High-pressure Engine Plugs.

Fusing points of the metals used in the alloys, of Lead, 612°; of Bismuth, 506°; of Tin, 442°.

Lead.	Tin.	Bismuth.	Alloy begins to solidify. Fahrenheit.	Stationary point. Fahrenheit.
26	8	...	529	353
23	...	...	521	353½
20	...	...	492	354
48	...	8	481	280½
16	...	...	475	354
44	...	8	474¾	280½
40	...	8	466½	280¼
10	...	...	430½	355
12	...	...	415	354
8	...	...	393	355
...	...	0·2	387	351
...	...	0·4	375	349
...	...	0·6	369	345¼
...	9	...	368½	352½
8	10	...	366½	353
...	8	...	364½	353
...	...	1	362	339¾
22	...	8	358	280¾
20	...	...	352	279
8	...	1·4	347	335
...	...	1·8	343	331
...	...	2·2	331	326
8	...	2·6	326	...
...	...	3·0	321	...
...	...	3·4	316	...
...	...	3·8	311	...
...	...	4·6	301	...
...	...	5·4	296½	...
...	...	6·2	294½	...
...	...	7·0	288½	...
...	...	7·6	283½	...
...	...	8·0	272	...

their velocity being precisely the same, except for a short time, by mere chance ; and when this is not the case, a most destructive rubbing immediately takes place. When two are working together, for instance, with driving wheels 5 feet 6 inches in diameter, the circumference will be 17·2787 feet, and at a speed of 40 miles an hour, which is 211200 feet, or 3520 feet per minute, equal to 58·66 feet per second, these wheels must revolve 12223 times in an hour, or 203·71 times per minute, equal to 3·395 times per second.

Now, if we only take half this velocity, or 20 miles an hour, or 105600 feet for the one engine, and 19 or 21 miles, or 100320 and 110880 feet respectively for the other, we have at once a rubbing motion of no less than 5280 feet per hour, or one mile in twenty, with a rubbing instead of a rolling motion. In fact, the rubbing will always be equivalent to the difference between the velocities of the two engines, and the loss of power, the wear and tear, and the injury to the machinery, by the extra steam which must be brought on all the working parts, if the above be true, may readily be imagined. A self-registering counter, fixed to ascertain the number of strokes, would easily settle this point ; to do which, it must trace the work of each engine on paper, similarly to the self-acting anemometer of Mr. Osler of Birmingham. But for our own parts no proof is required. We are certain it is not the case, and that the speed of both engines becomes equalized almost immediately after they start ; that engine which would travel the fastest, doing the largest proportion of the work, and thus relieving the pistons of the other, by drawing her along at her own rate, as she would, in fact, if the steam were shut off altogether. A strong man and a weak man working at a winch is an exactly similar case.

Before long there is no doubt that signals will be established along all considerable lines of railway. The use of them is sufficiently obvious, and they might be turned to profit also, by conveying messages of all kinds, at the rate of

so much per word; they would thus, instead of being a cost to the railway company, become a source of emolument. Communications throughout a length of 100 miles, when they can be made at one signal from each station, would be transmitted in about a minute and a quarter, and any ordinary message out of the usual course in about half an hour; a telegraph would be prevented from working by the weather, about two months a-year in the aggregate.

There is nothing so easy as to make a telegraph book; in fact, it is only numbering a dictionary, and the thing is done. In fact, hundreds of messages may be sent on the usual address of a newspaper, without the possibility of the post-office being at all aware of anything of the kind being carried on. In the case of a railway, each head of the different departments should send in lists of the various messages most likely to be wanted, and these could be added to, as time developes what is required.

The original expense of such a thing would probably be about L.260 each station, and the annual expense about L.77 per station; to which would have to be added the salary of the superintendent, clerks, and a few supernumerary men. Their great use renders them most desirable things. For instance, an accident happens to an engine ten miles from an engine station. The telegraph would send out another engine in a minute, with any commonly good look-out; whereas, to send on foot would require two hours, thus deranging the time of all the succeeding trains. As another instance, a train starting from one end to the other of the line, perhaps leaves 50 passengers at some intermediate town; the telegraph might immediately make this known to the clerk of that station, who, if he had few passengers ready for the train, could prepare goods' waggons to put on, so that the engine should not go with half a load; a matter of great importance, for the power absorbed by an engine before it can put itself in motion, being one-third of its whole power,

it follows that the relative expenditure of power per ton per mile, is nearly six times greater with a load of 10 tons than it would be with a load of 100 tons.

When accidents do happen upon railways, they may generally be expected to be extremely serious, and no means should be left unprovided, for immediate assistance being dispatched; even an advice carriage, which might be worked at 20 miles an hour, would be but a slow method, compared with a telegraph, for instance, if medical assistance, or what is more likely, surgical assistance, was wanted. In many cases, it will be highly advantageous, particularly in a pecuniary point of view, to run trains at different velocities, passing each other by means of sidings, the expense of locomotive transport increasing so much with an increased velocity. This desirable method will no doubt eventually be much practised. It would be almost impossible without a telegraph.

The effects of high wind upon a train, especially a side-wind, which binds the flanges of the wheels against the rails, and very much impedes the velocity, as well as increasing the wear and tear, renders it a desirable thing to have its force measured at all the principal stations, so that whenever it exceeds a certain standard, to be determined by experiment, a second engine may be sent out to assist the train. The most complete instrument for this purpose is the anemometer, invented by Mr. Osler of Birmingham, now used at the Philosophical institution of that town, at Plymouth, and in other places. This also combines so many other arrangements, as well as that for measuring the force of the wind, each of which it transfers by machinery to paper, that it is in fact the heavens registering themselves, and for a cost of about L.50 leaves nothing to desire.

For railway purposes merely, a more simple contrivance will be sufficient, although the cost will not be very materially decreased, if it be fitted up with the requisite attention to convenience as well as accuracy. For instance, if

a vane with a long tail, high above the top of the engine-house, and having at its pointing end a board one foot square, be fitted up in the following manner, it will be sufficient for all the wants of the locomotive department. The vane should be fixed on a hollow pole, which should turn with it and descend through a tube down to about five feet of the floor of the engine-house, where there should be a horizontal dial-plate, on which should traverse a pointer fixed to the vane-pole. This pointer would always indicate the direction of the wind; and in order to ascertain its force, the board, one foot square, on the pointing end of the vane, should act on a spiral spring, and work a drum by a wheel and pinion, communicating by a cord, with a similar drum at the bottom of the vane-pole, where a vertical dial-plate should be fixed, on the outside, and opposite to the lower drum, on which a hand traversing round the vertical dial-plate would shew the force of the wind.

According to the power of the engine, and the nature of the usual traffic, experience will soon point out when a second engine ought to be dispatched; and a table being formed for each point of the compass for this, should then be invariably acted on at all times, unless other local circumstances occasioned any alterations in the general average of the loads.

To estimate the force of the wind, we have, by the experiments of Dr. Hutton, a plane surface of one square foot, at a velocity of 20 feet per second, suffering a resistance of 12 ounces; and as it varies very nearly as the square of the velocity, we have in pounds, calling f any other force, and v the velocity,

$$\sqrt{\frac{3}{4}} : \sqrt{f} = 20 \text{ feet} : v \text{ feet},$$

and as the number of feet per second, multiplied by ·6818, produces the number of miles per hour, the above becomes, for miles,

$$\sqrt{\frac{3}{4}} : \sqrt{f} = 13{\cdot}636 : v \text{ miles.}$$

$$\text{or } \frac{1{\cdot}732}{2} : \sqrt{f} = 13{\cdot}636 : v$$

$$\text{or } {\cdot}866 : \sqrt{f} = 13{\cdot}636 : v,$$

whence the velocity in miles per hour is

$$v = \frac{13{\cdot}636}{{\cdot}866}.\sqrt{f}, \text{ or } 15{\cdot}746\sqrt{f} = v,$$

and we have also sufficiently near

$$f = \frac{v^2}{248}.$$

Hence we obtain the results given in the following table;

Velocity in miles per hour.	Force of wind in avoirdupois pounds.	Velocity in miles per hour.	Force of wind in avoirdupois pounds.
10	0·4	50	10.1
15	0·9	55	12·2
20	1·6	60	14·5
25	2·5	70	19·7
30	3·6	80	25·8
35	4·9	90	32·7
40	6·5	100	40 3
45	8·2		

and for every useful purpose, the force may be had within $\frac{1}{248}$th of the above by using this simple formula,

$$f = {\cdot}004v^2.$$

So much has been said about the inconvenience and danger of tunnels, that it is necessary, whilst there are yet so many railways to be called into existence, to state that there is positively no inconvenience whatever in them, except the change from day-light to lamp-light. This matter was clearly investigated and proved upon the London and Birmingham railway, a special inspection having been there made in the Primrose-hill tunnel by Dr. Paris and Dr. Watson, Messrs. Lawrence and Lucas, surgeons, and Mr. Phillips, lecturer on chemistry, who reported as follows:—

"We, the undersigned, visited together, on the 20th of February 1837, the tunnel now in progress under Primrose-hill, with the view of ascertaining the probable effect of such tunnels upon the health and feelings of those who may traverse them. The tunnel is carried through clay, and is laid with brick-work. Its dimensions, as described to us, are as follows: height, 22 feet; length, 3750 feet; width, 22 feet. It is ventilated by five shafts, from 6 to 8 feet in diameter, their depth being 35 to 55 feet.

"The experiment was made under unfavourable circumstances; the western extremity being only partially open, the ventilation is less perfect than it will be when the work is completed; the steam of the locomotive engine was also suffered to escape for twenty minutes, while the carriages were stationary, near the end of the tunnel; even during our stay near the unfinished end of the tunnel, where the engine remained stationary, although the cloud caused by the steam was visible near the roof, the air for many feet above our heads remained clear, and apparently unaffected by steam or effluvia of any kind; neither was there any damp or cold perceptible.

"We found the atmosphere of the tunnel dry, and of an agreeable temperature, and free from smell; the lamps of the carriages were lighted; and in our transit inwards and back again to the mouth of the tunnel, the sensation experienced was precisely that of travelling in a coach by night between the walls of a narrow street; the noise did not prevent easy conversation, nor appear to be much greater in the tunnel than in the open air.

"Judging from this experiment, and knowing the ease and certainty with which thorough ventilation may be effected, we are decidedly of opinion that the dangers incurred in passing through well-constructed tunnels are no greater than those incurred in ordinary travelling upon an open railway, or upon a turnpike road, and that the apprehensions which have been expressed, that such tunnels are

likely to prove detrimental to the health, or inconvenient to the feelings of those who may go through them, are perfectly futile and groundless."

The above will, of course, set the question at rest, especially as the Leeds and Selby tunnel, only 17 feet in height, and 700 feet in length, is found to produce no inconvenience ; and as any persons may now try the experiment themselves on longer tunnels than even that at Primrose-hill. We may instance the tunnel near Kilsby, on the London and Birmingham railway, which is 2425 yards long, and traversed without the slightest inconvenience or sensation of cold or damp ; the change experienced being merely that from sunshine to shade, and from daylight to lamplight, and this latter only in those seasons of the year when the days are considerably longer than the nights.

The quantity of friction in well-formed carriages we consider as certainly not more than 8 lbs. per ton ; but as about 9·3 lbs., or $\frac{1}{240}$th of the weight, will perhaps be a more general average, we here give a table for the total resistance arising from gravity and friction, calculated from the following formula.

$$G+F=\sin I+\frac{1}{240}=\frac{H}{L}+\frac{1}{240},$$

where G is the effect of gravity, the weight being taken as unity, I the inclination of the plane, H its height, L its length, and F the friction, the numbers in the table on the following page being the values of the right-hand member of the equation.

For any lesser inclination, divide 1 by the length of the plane to a height of unity, or find $\frac{H}{L}$, and add to the quotient in either case ·004167.

To use the table, look along the upper column for the hundreds, and down the left-hand column for the tens of the rate of inclination ; and at the point of intersection will be found a number which is to be multiplied by the total

Inclination of the plane equal to 1 *in*

	0	100	200	300	400	500	600	700	800	900,
0	·004167	·0141667	·0091667	·0075	·0066667	·0061667	·0058333	·0055953	·0, 54167	·0052778
10	·1041667	·0132575	·0089285	·0073925	·0066057	·0061275	·005806	·0055752	·0054013	·0052656
20	·054167	·0125	·008712	·0072917	·0065477	·0060898	·0057796	·0055555	·0053862	·0052537
30	·0375	·01213	·0085144	·007197	·0064923	·0060535	·005754	·0055316	·0053715	·005242
40	·029167	·0113095	·0083333	·0071079	·0064394	·0060185	·0057292	·005518	·0053572	·0052305
50	·024167	·010833	·0001667	·0070238	·0063889	·0059848	·0057052	·0055	·0053432	·0052193
60	·020833	·010417	·0080129	·0069444	·0063406	·0059224	·0056818	·0054825	·0053295	·0053083
70	·018452	·01001467	·0078704	·0068694	·0062944	·0059211	·0056592	·0054654	·0053161	·0051976
80	·016667	·009722	·0077381	·0067983	·00625	·0058908	·0056373	·0054488	·005303	·0051871
90	·0152778	·0094298	·007615	·0067308	·0062075	·0058616	·005616	·0054325	·0052903	·0051768

weight of the carriage and its load in lbs. for the total resistance. Thus for a carriage weighing 8000 lbs., at an inclination of 1 in 560, we have $8000. \cdot 0059524 = 52 \cdot 6192$.

Calling W the weight of the carriage, the friction alone will vary from $\frac{W}{550}$ to $\frac{W}{200}$, according to the care with which it is constructed, and this may be divided into that arising from the wheels on the rails, or the rolling friction, which is a constant quantity, more or less, according to the strength, or the stiffness of the rails, $=\frac{W}{850}$, the remainder being due to the rubbing of axles on their bearings. A great deal depends upon the unguent used, both as it respects quantity and quality. A wheel loaded with from 1 to 4000 lbs., and turned on its axle on a half bearing by a weight and rope, which detached itself after falling 30 feet, leaving the wheel to revolve till its own friction brought it to rest, made 36 revolutions, when nearly deprived of oil, and 278 revolutions when the oil was heaped on that side of the bearing which the circumference of the axle approached as it turned round. The ratio of bearing surface of the axles has also a considerable effect. This should not exceed 90 lbs. per square inch, and the length of bearing should not be much less than twice the diameter of the axles. Under these circumstances, friction on railways will be uniform at all velocities with well made carriages, and will be in the ratio of the weight.

The friction of engines, without any load, and exclusive of the tenders, will be in the average ratio of the diameter of the wheels, and nearly as their weight; $8\frac{1}{2}$ tons, with five feet wheels, being 15 lb. per ton; with a load, 1 lb. per ton must be added.

The friction of edge-rails to that of plate rails, is as 17·5 to 27·8. The wear and tear of ropes on inclined planes is about $\frac{1}{4}$d. per ton per mile; and their friction, either self-acting or with fixed engines, will vary from $\frac{1}{25}$ to $\frac{1}{3}$ of the

weight of rope wheel and sheaves in action *plus* the pressure of the rope on the wheel. This quotient will have to be divided by the difference in diameter between the sheave and its pin, and an allowance must be made for any curves in the line of direction.

The adhesion of engines may be taken as at least equal to $\frac{1}{10}$th part of the weight on the driving wheels. This will enable them to draw in the following proportions for each ton of the weight under the most unfavourable circumstances, and may be much increased when the weather and all other circumstances are in the most advantageous state.

Inclination.	Load in tons for each ton adhesion.	Inclination.	Load in tons for each ton adhesion.
Level.		Level.	
1 in 4480	26·25	1 in 500	17·25
... 3360	24·21	... 448	16·59
... 2240	23·58	... 400	15·88
... 1680	22·40	... 350	15·03
... 1120	21·33	... 300	14·03
... 1000	20·86	... 250	12·83
... 900	20·37	... 200	11·37
... 800	19·82	... 150	9·56
... 700	19·14	... 100	7·25
... 600	18.31		

In the common steam engine, the power is as the area of the piston, and the pressure of the steam on it. But in the locomotive engines this is not the case; for the power of raising steam in any quantity, which may always be had in a stationary engine by increasing either the size or the number of the boilers, has a limit in the locomotive, determined by the weight to which the engine must be restricted. The power in this case resides in the capability of the engine to generate a given number of cylinders of steam in a certain time, and not in the diameter of the piston.

The evaporation is produced partly by radiant heat com-

municated to the water surrounding the fire-box, and partly from that which is transmitted by the hot air passing through the tubes, the effect of the former being to the latter as 3 to 1. At a velocity of 18·88 miles per hour, M. Pambour found that 55·82 cubic feet of water were evaporated per hour, with a heating surface exposed to radiation of 43·12 square feet, and a surface exposed to the heated air of 288·35 feet, equal together to 139·24 square feet of radiating surface; and calling a the former surface, and b the latter, we shall have the evaporating power of different engines at the above velocity, $e = a + \frac{b}{3}$, and reducing the communicative to the equivalent radiant heat as above, we get 0·4 cubic feet evaporated per hour for each square foot of radiating surface, of which, from blowing off, loss from the steam ports, and half an inch at each end of the cylinders, the effective steam is only 0·3 cubic feet for each square foot of radiating surface. The piston must move about 300 feet per minute to work the blast properly, which generally requires 6 lb. per square inch, at 25 miles per hour, and at the highest velocities, will take one-third the power of the engine.

The coke consumed in the best kind of engines, will be about one-fourth of a pound per ton per mile, gross load, and one-fourth of a gallon of water, provided the load is proportioned to the capability of the engine. A great deal also depends on the quality of the coke; and as the power of an engine consists so much in the quantity of water it can evaporate, we subjoin a Table giving the load to the nearest ton and velocity on different inclinations, when sixty cubic feet of water per hour can be converted into steam, that being the capability of the best modern engines.

The expenses of railroads are not yet well understood, and are very variable. For instance, in America, the Boston and Worcester costs L.157 per mile, and the Utica and Shenectady, L.363 per mile; whilst in England the Liver-

Evaporation 1 *cubic foot per minute. Gross Load exclusive of Tender.*

Plane.	10 miles per hour.	12½ miles per hour.	15 miles per hour.	17½ miles per hour.	20 miles per hour.	22½ miles per hour.	25 miles per hour.	27½ miles per hour.	30 miles per hour.
Level.	346	251	188	143	109	82	61	44	30
1 in 4480	326	236	176	134	102	77	57	41	27
... 2240	308	223	166	126	95	72	53	37	25
... 1120	276	200	148	112	84	63	46	32	20
... 1000	270	195	145	109	82	61	45	31	19½
... 900	265	191	142	107	80	60	43	30	19
... 800	256	184	137	102	77	57	41	28	18
... 700	246	177	131	98	74	55	39	27	16
... 600	235	169	125	93	70	51	37	25	15
... 500	220	158	116	87	65	47	34	22	13
... 400	201	144	106	78	58	42	29	19	10
... 300	175	125	91	67	49	35	24	15	7
... 200	138	98	70	51	36	25	16	8	2
... 100	84	55	38	25	16	9	3	...	...

pool and Manchester costs L.1000. Again, the latter costs L.444 per mile, for maintenance of the way, whilst the Leicester and Swannington, a coal line, was let for four or five years, at L.70 per mile, and is now let for less, the company finding engines and ballast, at which price the contractor is supposed to have made L.500 a-year, besides interest upon the cost of his waggons. About 180,000 tons yearly pass on this line. The engines weigh from three to twelve tons, and the waggons thirty-eight cwt. carrying four tons nett. The locomotive power is rather more than one-fourth of a penny per ton per mile.

The maintenance of the way upon the Grand Junction railway, for eighty-two miles to Newton, has been let at L.244 per mile, including rails, chairs, bridges, and every thing. We have no doubt this is amply sufficient. They pay L.20,000 a-year to the Liverpool and Manchester company for the use of their line and offices. The Great West-

ern railway, under unfavourable circumstances, has been let at L.416 per mile; and the repairs to the London and Southampton line are divided, the company finding all materials, and contracting for their labour only, for which they pay L.140 per mile, including the use of tools. But the best data to found any calculation on this varying expenditure, are those contained in the reports published by the Directors of the Liverpool and Manchester railway, for the five half years ending the 30th of June 1834. We shall endeavour to set this calculation in its true light, which has not yet been done. The following are the various items of expenditure, exclusive of interest, with which we have nothing to do.

Liverpool and Manchester Railway expenditure for five half years ending June 1834, exclusive of interest :—

Locomotive power, including new engines.........	L.67552
Maintenance of way, including new rails............	38306
Coaching, including compensation for lost goods, repairs, and office expenses........................	32628
Carrying, including waggon repairs, carting, and compensation..	63279
Stationary engine expenses, including ropes, &c...	4728
Police disbursements..	5285
Engineering department....................................	2084
Direction, office expenses, rent, taxes, bad debts, and sundries...	23842
Total, exclusive of interest..............	L.237,704

We have included the cost of new engines in the locomotive power expenditure, as otherwise we should have had to allow an uncertain amount for depreciation. For the same reason we have included the cost of new rails in the disbursements for the maintenance of way ; whereas former computers have only included the cost of new blocks and sleepers. In the coaching and carrying departments are included the following items, which we shall afterwards use.

Coach repairs......................	L.7957
Waggon repairs..	6436

Let us now see what duty has been performed for these several amounts of expenditure:—

944,113 *passengers conveyed in* 15,831 *trips, or* 59.63 *per trip* = $34\frac{1}{2}$ *miles on a level.*

For power, Goods, nett, 440229 tons, viz. goods 345463 $+ \text{coals } \dfrac{189533}{2}$

... Goods, gross, 676065 tons, viz. 440229 + waggons 188669 + empty do. at $\frac{1}{4}$ = 47167.

For way, Goods, nett, 489614 tons, viz. 440229 + $\dfrac{7411 + 91358}{2}$ = Bolton tonnage.

... Goods, gross, 751914 tons, viz. 489614 + waggons 209840 + empty do. 52460.

For power, Goods, trips, 11702 at 37·63 tons per trip.

For way, ... 13014 ...

The distinction shewn here between the power and the way arises from a small portion of the coals and the Bolton tonnage not being drawn by the company's engines; and hence these have to be omitted in any calculations on the cost of locomotive power, but are retained in the expenses of keeping in repair the permanent way. The number of trips has also to be augmented by an average allowance for the above tonnage. For computing the expense of the way, we must likewise include the weight of the engines and tenders, say 15 tons each. We then have

Goods...........................	751914	
Engines 13014, at 15 tons...	195210	
Total weight of goods' trains		947124
Passengers, at 15 to a ton......	62941	
Luggage, at 28 lbs. each......	11801	
Trains, 15831· 16.3655......	259082	
	333824	
Engines, 15831 at 15 tons	237465	
Total weight of passenger trains		571289
Total load passing on the way		1518413

In the above, we have allowed coach room for 64 passengers per trip, and have taken the weight of a first-class train at 21 tons, and a second class at 12·6 tons; the relative numbers of each being at the time we speak of, 13 to 16; hence the average weight of a train is $\frac{21.13+12,6.16}{13+16}$ $=$ 16·3655 tons, and more on longer lines from the luggage being heavier.

We have now to deduce the drawn and the passing weight over 1 mile upon a level, calling the Liverpool and Manchester railway equal to $34\frac{1}{2}$ miles on a level, when due allowance is made for the gradients.

Drawn weight, 1 *mile on a level.*

		Tons.
11702 trips	Goods, nett..........	$440229 \cdot 34\frac{1}{2} = 15187900$
	Goods, gross.........	$676065 \cdot 34\frac{1}{2} = 23324242$
15831 trips	Passengers nett, including luggage,	$74742 \cdot 34\frac{1}{2} = 2578599$
	Passengers, gross,	$333824 \cdot 34\frac{1}{2} = 11516928$

Passing weight, 1 *mile on a level.*

		Tons.
13014 trips	Goods, nett..........	$489614 \cdot 34\frac{1}{2} = 16891183$
	Goods, gross.........	$947124 \cdot 34\frac{1}{2} = 32675778$
15831 trips	Passengers, nett....	$74742 \cdot 34\frac{1}{2} = 2578599$
	Passengers, gross....	$571289 \cdot 34\frac{1}{2} = 19709470$

We now require the ratio of expenditure for passengers and goods, for locomotive power and maintenance of the way. This has generally been taken in proportion to the number of trips with each, which is clearly wrong. Both the weight and the velocity are evidently functions of the expenditure, taking the drawn weight in estimating the cost of the power and the passing weight for that of the way; and as the cost of passengers and that of goods is not separated, which indeed could hardly be done for the way, we have no guide, and can only make an approximation, by taking the cost directly as the weight and velocity. We have then

For locomotive power

23324242·15 : 11516928.25 or 349863630 : 287923200,
or as 1·215 to 1.

This gives us in money,

Goods...	L.37054.5
Passengers....................	30497.5
Total.................	L.67552

A similar result drawn from the number of trips only, would give for the goods, L.28710, and the passengers L.38842, which is clearly inadmissible; unless we are prepared to say that the locomotive power is used in a most disadvantageous manner, of which we have no evidence. Hence, if we multiply the number of passengers by 0·353585, or which will be sufficiently accurate, by 0·3536, it will give us the total weight drawn in trains, averaging as those did on the Liverpool and Manchester line at the time in question; or, in other words, there are 2·8282 passengers to a ton gross weight.

In order to apportion the expense of maintaining the way between the goods and passengers, we have,

For maintenance of the way,

32675778·15 : 19709470·25 or 490136670 : 492736750,
or as 1 : 1·005.

This gives us in money such a small difference from equal proportions, that we may safely venture to place half the expense on each; always premising, as we have before explained, that the workmanship in the waggon springs, wheels, and axles, is to be considered as of the best description, without which the expense may be almost anything.

The result deduced from the number of trips would have given us the goods' expense to the passengers, nearly as 16 : 22, an additional proof that this method is very erroneous. We are aware of the difficulties which envelope the whole question, especially in first working a railway, when the embankments settle down and render very expen-

sive repairs necessary, without a single vehicle passing over the road, whilst the more it is used, the sooner it will get in perfect order. Nor are there any data to guide us correctly, as respects the effect of velocity; but from an attentive consideration of the subject, combined with a comparison on many lines, we believe the foregoing method to be that which agrees best with practical results, and with this we must rest satisfied till more experimental knowledge is acquired.

For the locomotive power, the cost of new engines and repairs must now be separated from that of the working expenditure in coke, oil, grease, waste, wages, &c. We shall find this to stand as follows:

Repairs, &c.	L.42376
Working expenses	25176
Total	L.67552

This again will divide itself into,

Repairs, &c., Passengers	L.19131
... ... Goods	23245
Total	L.42376
Working expenses, Passengers	L.11366
... ... Goods	13810
Total	L.25176

In the same manner we may divide the expense of maintaining the permanent way into

Wages	L.19216
Materials	19090
Total	L.38306

This comes so very near a half, that we may safely estimate it at that quantity, or at one-fourth of the total, as follows:—

Wages, Passengers	L.9576.5
... Goods	9576.5
Total	L.19153

Materials, Passengers	L.9576.5
... Goods	9576.5
Total	L.19153

Reducing the whole of the preceding items, we get, as in the following Table, the expenditure per ton per mile.

Cost of the following items on the Liverpool and Manchester railway reduced to a level.	Passengers per mile per ton. Gross.	Passengers per mile per ton. Nett.	Goods per mile per ton. Gross.	Goods per mile per ton. Nett.	Total goods and passengers per ton-per mile. Gross.
	d.	*d.*	*d.*	*d.*	*d.*
Locomotive power,					
Total	·6355	2·8385	0·3813	0·5855	0·4563
Repairs	·3987	1·7806	0·2392	0·3673	0·2919
Expenses	·2368	1·0579	0·1421	0·2182	0·1734
Maintenance of way,					
Total	·2332	1·7826	0·1407	0·2721	0·1755
Wages	·1166	0·8913	0·0704	0·1366	0·0878
Materials	·1166	0·8913	0·0703	0·1365	0·0877
Coach repairs	...	0·7406	...	...	...
Waggon repairs	...	...	...	0·1017	...

The police expenses are about L.75 per mile, including gatekeepers and switchmen ; and this would of course be doubled for a night and day line. The porterage of the goods at the termini, costs 8¼d. per ton, and has been for some time paid at that rate by contract.

As an example of the mode of estimating per ton, and per passenger per mile, the following accounts for the Stockton and Darlington railway will be useful. The traffic on this line consists of coals carried on an average 20

miles per trip, with 63 tons 12 cwt. nett. Goods averaging 12 miles, and passengers the same distance, are conveyed indiscriminately in the same train.

The following statement is for the half year ending the 31st December 1834:—

			Trips.
No. of trips with coals equivalent to 20 miles per trip			3682·5
The expenses of locomotive power, including the repairs, working, fuel, wages, &c., and interest on capital	L.8310	14	9
Which gives per trip	2	5	1·61
This gives per ton per mile	0	0	0·4258
In the above is is included			
Water stations	L.126	12	1
Agencies	81	18	4
Miscellaneous	294	8	4
Total	L.502	18	9

No. of trips of 12 miles, with goods and passengers,	2261¾		
No. of passengers conveyed one mile	398244		
No. of passengers conveyed one trip of 12 miles	33187		
Expense per trip of 12 miles	L.0	12	3·35
Expense per passenger per trip	0	0	10·04
Receipts per trip of 12 miles	0	18	0·61
Receipts per passenger per trip	0	0	1·276
Total cost of locomotive power for the half year	L.1388	12	10
Total receipts from passengers for ditto,	2041	7	4

The cost for goods and passengers is as follows:

Working the engines	L.1207	5	1
Guards and clerks' salaries	187	2	10
Repairs of coaches	34	16	3
Miscellaneous	337	12	2
Total	L.1766	16	4

	Brought over—Total......	L.1766 16 4
Deduct proportion of expense for some coals drawn by passenger engines..........	L.79 1 6	
Deduct for goods 7185 tons, 12 miles at $\frac{6}{10}$ths of a penny per ton per mile............	215 10 11	
Expenses in the goods' department....................	83 11 1	
		378 3 6
Expense for passengers only.................		L.1388 12 10 as above.

Hence 7185 tons of goods cost per ton per mile..........	L.0 0 0·8337
Being L.215, 10s. 11d. + L.83, 11s. 1d. total cost on................................	299 2 0

The performance and cost in locomotive power for five of the principal passengers' and goods' engines during the six months, is as follows:

Engines.	12 mile trips.	Wages, coal, oil, tallow, hemp, &c.			Repairs.			Total.		
		L.	*s.*	*d.*	*L.*	*s.*	*d.*	*L.*	*s.*	*d.*
North Star.	$370\frac{15}{24}$	74	7	8	112	8	3	186	15	11
Planet.......	$263\frac{10}{24}$	44	1	2	34	18	1	78	19	3
Globe........	$286\frac{8}{24}$	27	16	6	207	7	9	235	4	3
Shildon.......	$193\frac{8}{24}$	15	8	0	136	11	7	151	19	7
Wilberforce	836	170	0	1	310	14	10	481	0	11
Average.....	$389\frac{8}{24}$	66	7	$10\frac{1}{2}$	160	8	$1\frac{1}{4}$	226	15	$11\frac{3}{4}$

The performance of eleven of the principal coal engines is as follows, the trips being equivalent to 20 miles each, with 63 tons, 12 cwt.

Engines.	No. of 20-mile trips.
Royal George,......	293·01
Locomotive,........	222·93
Coronation,.........	262·82
Director,...........	286·11
Lord Brougham,...	236·07
Adelaide,...........	237·56
Earl Grey,.........	278·03
Lord Durham,......	249·89
Experiment,........	227·78
William,............	212·46
Rocket,............	217·85
Average,...	247·11

The estimated expenditure per trip of 20 miles with coals, when this railway company worked their own engines, was, for the years 1833–4:

Locomotive power, total,	L.2	2	7·344			
Interest of capital, rent of shops, &c.	0	3	1·187	L.2	5	8·531
The same expense when the power was let to contractors in the years 1834–5, . .	2	2	4·8			
Water engines, agency, and superintendence, . .	0	1	5·25	2	3	10·05
Saving per trip of 20 miles, with 63 tons, 12 cwt. nett, in 24 waggons, . .				L.0	1	10·481

The cost of L.2, 2s. 4·8d. to the contractor may be divided as follows:

Engine-man's wages, .	L.0	6	1½
Fireman's do. .	0	3	0
Engine bars, . .	0	0	8
Coals, . . .	0	4	9¾
Oil, tallow, and white lead,	0	3	7¼
Hemp and spun yarn, .	0	0	4
	L.0	18	6·5

Brought over,	L.0	18	6·5
Interest of capital, .	0	1	11·386
Rent of shops, . .	0	1	1·801
Repairs and profit, .	1	0	9·113
Per trip of 20 miles,	L.2	2	4·8
Or, per mile:			
Wages and consumable articles,	L.0	0	11·125
Interest and rent of shops,	0	0	1·85935
Repairs and profit, .	0	1	0·45569
	L.0	2	1·44

The table on the opposite page shews the amount of repairs for two years, 1835 and 1836, to seven engines on the Stanhope and Tyne Railway.

The work performed by these engines in the two years, was as follows:

	Tons, 1 mile. Gross load.	Tons, 1 mile. Nett load.
Two years, .	10322616	4825309
Per annum, .	5161308	2412654
Per engine, per annum,	737330	344665

The comparative cost of the different modes of transit is, under all circumstances, strongly in favour of railways. For instance, in waggons travelling $2\frac{1}{2}$ miles an hour, the cost of each ton, per mile, for goods, is about $7\frac{3}{4}$d., of which nearly 3d. is the cost of horsing. In vans travelling at 4 miles an hour with lighter goods, the expense is nearly 1s. per ton, per mile, the horsing costing rather above 4d. of this sum. The expenses of four-horse stage coaches, vary from L.4 to L.5 per lunar month, per double mile, according as their rate of travelling varies from 8 to 10 miles an hour; their hire and repairs cost $2\frac{1}{2}$d. per double mile; the duty is 3d. per double mile; and the horsing is 2s. The coachman and guard are seldom paid except by the passengers, say 10s. 6d. per week for them at the outside; and for tolls and incidental charges 6d. per mile; being a large allowance. The tolls on the Holyhead road,

	Materials.			Labour.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.
Preparing engine, cleaning do., adjusting pistons and slides, packing glands, and putting on man-hole doors, ...	4	9	0	73	2	9	77	11	9
Lifting, stripping, and putting together, ...	...			196	16	8½	196	16	8½
Carriage, and axle-rod brasses, ...	21	7	5¾	20	17	6	42	4	11¾
New wheels, and taking off and keying on, ...	380	1	5½	68	4	6	448	6	0¼
Connecting rods, straps, keys, brasses, and liners, ...	2	1	3	9	13	2¼	11	14	5¼
Steam pipe regulator, ...	6	10	11	19	13	2½	26	4	1½
Cross heads, cross bars, parallel blocks and bars, ...	0	18	7½	8	1	1¼	8	19	8¾
Pistons, ...	29	17	6	52	9	3	82	6	9
Weigh shafts, slide spindles and shafts, ...	24	0	8½	43	15	10¼	67	16	6¾
Pumps, plungers, glands, gland bolts, clack seats, union pipes, suction pipes, and hose,	103	13	9¼	79	13	7¼	183	7	4½
Lifting apparatus, with eccentric rods, straps, sheeves, forked lever, clutch ring, and reversing lever, ...	14	4	3¾	53	13	11¼	67	18	3
Side rods, keys, liners, brasses, straps, turning crank pins, and keying-on cranks, ...	8	7	8	32	4	3¼	40	11	11¼
Frame with hand railing, spring, spring pins, links, frame ends, buffers, and foot board,	30	18	2	76	0	9¼	1 6	18	11¼
Coupling bar, drag bolt, drag plates, cotters and ferrules, ...	16	14	7	17	6	2¾	34	0	9¾
Fire box, ...	46	14	4	105	18	5¾	152	12	9¾
Tubes, taking out and putting in do., and putting in hoops, ...	246	17	6	47	1	5¾	293	18	11¾
Smoke box, blast pipe, and chimney, ...	34	10	5¾	98	11	8¼	133	2	2
Fire frames and bars, ...	71	3	8	17	9	10¼	88	13	6¼
Cleaning boiler, ...	0	1	6	19	7	5¾	19	8	11¾
Water guages, ...	0	15	11	0	18	1	1	13	0
Guage cocks, ...	1	13	7	11	16	1	13	9	8
Tools, ...	11	9	4¼	13	18	4¼	25	7	9
Painting engine, ...	...			18	5	2	18	5	2
Tender, ...	115	2	11	108	13	2¾	223	16	1¾
Total, ...	1166	3	0¾	1194	2	8¼	2360	5	10
Total, per annum, ...	583	1	6½	597	1	4½	1180	2	11
Total per engine, per annum, ...	83	5	11¼	85	5	11	168	11	10¼

one of the best in England, are not quite 4d. per mile, for a four-horse coach. This gives 1s. 9d. expenses per single mile, whilst the returns will be 2s. 6d. per mile. From this calculation we have excluded the charge for parcels, &c., leaving it to go, with the allowance for incidentals, to the support of the office establishments. The coaches which ran between Birmingham and London, prior to the opening of the railway, charged L.2, 10s. inside, and L.1, 10s. outside, the distance being 108 miles, and after the opening, L.1, 10s. inside, and 17s. out. Our computation of coach profits we know is under the mark. The cost of this mode of travelling is about 3d. per passenger per mile, or 3s. per ton, taking 12 passengers and their luggage to a ton. In canal carriage, the cost varies from 3d. to 5d. per ton per mile, in the fly boats going at the rate of 4 miles an hour; and by slow boats, from 1¼d. to 2d. per ton per mile, at the rate of 2½ miles an hour. The passenger boats, going 10 miles an hour, charge from 1d. to 1¼d. per passenger, per mile, or from 1s. to 1s. 3d. per ton of passengers, per mile.

The cost of carriage by railways worked with horses, is from 1½d. to 2d. per ton, per mile, for heavy, and 3d. to 3½d. for light goods, and from 1d. to 1½d. per passenger, per mile, or from 1s. to 1s. 6d. per ton of passengers, per mile. Those worked by locomotives charge about the same for goods, and rather more for passengers, or from 1½d. to 2½d. per mile on an average. These latter charges however are too high. The resistance by the several modes of transit, is for railways, 8 lbs. per ton; canals, 2¾ lbs. per ton, at 2½ miles velocity, 7 lbs. at 4 miles, 40 lbs. at 9 miles, and 60 lbs. at 11 miles, which is the greatest hitherto attained. Turnpike roads' waggons, 76 lbs.; vans, 71 lbs. at the before mentioned velocities; and coaches, 80 to 88 lbs. at from 8 to 10 miles an hour.

In whatever light we view the question, no other mode of transit can be put in competition with railroads, except the very slow carriage of heavy goods on canals. But this

is not a fair comparison, as speed must be taken into account as well as price; and we have no hesitation in saying that upon well managed and economically-conducted railroads, goods of every kind can be carried, with proper precautions, quite as cheap as by any canal, and with three times the speed at least. A great deal remains yet to be done in this department of locomotive transit, and the question cannot be decided on any railway with certainty, till it has been some time in operation, and the mode of working and maintaining it, and of economising the locomotive power expenses, are reduced to a well regulated system.

Many doubts were entertained, at an early period of the railway system, as to the performance of engines when snow lay on the rails to a depth which on the common roads interrupted the ordinary communications of the country; they have however completely triumphed over this difficulty; a striking proof of which took place on the Newcastle and Carlisle Railway; where the possibility of working the engines, under the above unfavourable circumstances, was put to the test on December 20, 1836, in the deep cutting through the Cowran hills, where the snow had accumulated to the depth of four or five feet, when the Hercules engine came down on the morning of the above day. Numbers of the country people assembled to see how it would act in such an emergency, and to render any assistance which might be necessary. On arriving on the spot, however, the engine dashed right into the drift, clearing its way through, apparently without any difficulty; the snow at the same time flying over the top of the engine chimney, like foam from the broken waves of a violent sea; and notwithstanding this and other similar obstructions, the train came down from Greenhead, twenty miles, in one hour and a quarter, and their times of arrival were properly kept up, whilst all the communications by the ordinary roads were more or less seriously obstructed, if not entirely cut off.

Hence any of the so often proposed plans for sweeping

or scraping the rails will rarely be found necessary, much less the plan seriously proposed and patented so late as 1831, of making the rails hollow and filling them with hot water in winter. In the extreme case of rain succeeded by frost, thus forming a coat of ice upon the rails, it will generally be found sufficient to place a waggon, or any other empty light vehicle in front of the engine, which will break up the ice sufficiently to allow of the necessary adhesion. The effect of severe frosts on the road itself will be found of infinitely more consequence, and is an additional reason why drainage should be scrupulously attended to in countries where much cold is experienced. The manner in which frosts act on common roads, is sufficient evidence of what may be expected on a railroad, if the water is not most carefully carried off from the ballasting.

In America, for instance, where railways were first laid down on blocks, similar to the way they are constructed in England, it was found that their severe winters completely disorganised them; splitting the blocks, throwing the rails out of guage, and even twisting them so as to render them unfit for the passage of the engines, and obliging the trains to travel at a reduced speed. From these causes, and as it was found necessary to relay the road after each winter, blocks have in a great measure been abandoned, longitudinal and cross sleepers being generally substituted, and laid on broken stones filled into trenches; but the evil is yet only partially remedied. It may, however, in all cases, be set down as a general rule, that where timber can be obtained cheap, it should be used in preference to blocks.

The difference, however, is necessarily so great between the railroads in that country and this, as very much to preclude comparison. Some of theirs are constructed of plate rails $2\frac{1}{2}$ inches wide, by half an inch thick, and weighing from 10 to 17 lbs. per yard; their curves and inclinations are such, from the nature of the country, as to render cross ties more frequently required than they are in English railroads.

Continuous stone bearings have also been tried in America; also piles at three feet distance, as supports to the rails, which are spiked down to them without the intervention of any chairs.

Several of their railroads are carried across valleys by means of wooden trestles, well braced together, and assisted by piles; the lower ends of which in soft ground are often left square instead of being pointed, as a means of affording additional stability. These sort of roads are in several cases carried over valleys of such a depth, as to occasion no small surprise to those only acquainted with the substantial embankments of England and most other parts of Europe. It must be confessed, however, that the Americans, in the expense of their railways, beat the old country hollow; and there are many things which we should be glad to see copied from them; we may instance their guards in the front to the engine to remove obstacles from the road, and their long and high carriages.

Some of their lines are worked by horses at the rate of 15 miles per hour; and on the locomotive lines, where the curves are bad, the driving wheels are placed next the fire box, and the front part of the engine is supported on a four-wheeled truck, to which it is attached by a vertical pivot, whilst the weight rests on friction rollers; this management admits of a motion by which the wheels are in a great measure assisted in their passage round the curves, which in some cases have not more than 300 feet radius, whilst in others they have gradients of 1 in 110, and inclined planes rising 1 in 10.

Another striking departure from the method of constructing these works commonly adopted in England, has been introduced by Mr. J. K. Brunel on the Great Western Railway, with a view to an increase in speed, and also to obtain a more solid road, on embankments particularly. Instead of resting the supports of the rails, that is to say, the stone or wood bearings, whether longitudinal or transverse, on the

ballasting, where the repairs to the railroad consist in continually packing more ballast under the bearings, as they subside through the weights passing over them, or from the various other causes which affect them, Mr. Brunel has fixed his bearings at certain points, so that they cannot rise up nor go down, whereas in the usual mode of construction, it has only been attempted to prevent them from going down.

The guage of the Great Western Railway is 7 feet 2½ inches from centre to centre of the rails, and the width between the two lines is 6 feet. The mode of construction is as follows. (See Plate CCCCXX.) At every 15 feet in length along the railway, beech piles are driven into the ground, at 15 feet distance apart, transversely; they are driven from 8 to 10 feet in cuttings, and in embankments, they are in general sufficiently long to go about the same depth into the original ground on which the embankment stands. These piles are formed to the proper length, and driven in, without any being cut off their heads, which are nearly level with the top of the ballasting, and when this cannot be effected, they are drawn and redriven. They do not stand in the middle of each line of rails, as will be seen by referring to the above measures and the plate, but are nearer each outside rail of the two lines.

To these piles double and single transverse ties, or sleepers, sometimes called transoms, are attached as follows: A square shoulder is cut, 1½ inches into the pile, on one side for the single ties, and on both sides for the double ones; the single ties are 6 inches broad, and 9 inches deep; the double ties are 6 inches broad, and 7 inches deep. They are made of American pine, and when let into the shoulders of the piles, they are securely bolted to them; the double ties are 13 inches, and the single ones 9 inches below the line of rails. On these are laid longitudinal timbers, 15 inches broad, and 7 inches thick; these are also of American pine, and are bolted to the cross ties with screw bolts and washers, the heads of which are countersunk into the longitudinal timbers.

The entire transverse section is horizontal where the railway is straight, and inclined according to the radius in curves; and when the whole is bolted together, it forms what is in fact a road at fifteen-feet bearings. The line is then ballasted, and the longitudinal bearings are packed in the usual manner with fine sand or gravel, till they are raised in the middle from a half to one-third of an inch; they are then planed to a uniform surface, and a plank of elm, oak, or ash, $1\frac{1}{2}$ inches thick, and 8 inches broad, is laid on them, with a copious intervening bed of tar, and nailed down ; the heads of the nails being punched in, to allow the plank to be planed; the upper surface of the plank slopes inwards 1 in 20.

The rails are screwed down to the plank and longitudinal bearer, after the former has been planed; with felt underneath them. The whole of the timber is kyanized, and the joints, butts, bolts, washers, keys, spikes, and nails, also the whole of the longitudinal bearers, are tarred. In fixing the rails, square-headed screws are used outside the rails, and countersunk ones inside, to be clear of the flange of the wheels ; the outside screw is first completely tightened and then the inner one, a roller weighing about 10 tons being previously drawn several times along the rail, and followed up closely by the screwing.

The principle on which the railway is intended to be constructed chiefly consists in the piles being a constant retaining power, holding the road down against the packing, which would otherwise force it up; so that this latter can be driven much harder in than by the ordinary mode. Mr. Brunel is said to calculate that he throws an upward pressure against the base of each longitundinal timber, equal to one ton per foot forward, or about one ton per square foot. He thus obtains 3 tons for every 3 feet length of rail, while a stone block containing 4 cubic feet, only weighs about a quarter of a ton, which is therefore the pressure with each 3 feet of rail laid in the usual way ; neglecting the impact with which the stone block is forced into its seat by the cuddy and lever,

a very uncertain quantity, but which perhaps never amounts to, on the whole, less than as 3 : 2 in favour of the longitudinal bearings. The timber used in a mile of this railway, is about 420 loads of pine, and 40 loads of hard-wood ; these require 6 tons of iron bolts, and 30,000 wood screws. The rails are about 44 lbs. per yard, and the cost of the first portion, laid from London to Maidenhead, including laying, ballasting, sidings, draining, and all other work, is stated at L.9200 per mile.

Such is the mode of construction on this railroad, which has so much agitated the minds, not only of the shareholders, but of the whole railway public. This, however, ought not to have been the case, for the matter lies in a very small compass, and a short experiment should have determined it ; it is merely a question of expense. The first outlay must, of course, be great, and it is only necessary to know whether the future saving will be commensurate with it. A desire for a greater width of guage seems now gradually gaining ground among those best entitled to judge on the subject, and the public will not long rest satisfied with a velocity of twenty miles an hour. Whether Mr. Brunel has taken the right measures to compass these desirable objects, will require much more room to discuss than we have here ; but this we know, that the Great Western, for the twenty-three miles now open to the public, is by far the smoothest and easiest line we have ever travelled on.

The relative ratio between the motion of the wheels and that of the piston will be much more advantageous at a given velocity as the wheels are large, within certain limits ; the greater degree of stability acquired, from the increased width of guage is also desirable, if not carried too far ; but we must confess we should ourselves be afraid of jumping from 4 feet 8½ inches, to 7 feet, without more experience. Another company jumped from 2 feet 9 inches to 5 feet in their length of bearing, and the result was sufficiently inauspicious.

The effect of the diameter of the wheels on the velocity of the piston, may be thus computed:

Let $v=$ the velocity of the wheels,
$p=$ the velocity of the piston,
$l=$ twice the length of the stroke,
} in feet,
$m=$ the number of miles per hour the engine travels.

We then have

$$v:p=3{\cdot}14159 . d:l,$$

$$\text{or, } pd . 3{\cdot}14159, \&c. =vl,$$

$$\text{and } v=88m \text{ feet per minute;}$$

$$\text{also } p=\frac{88 . m . l}{d . 3{\cdot}14159},$$

$$=\frac{28{\cdot}01127 . l . m}{d}.$$

This for all ordinary purposes may be taken at

$$p=\frac{28ml}{d},$$

with a stroke of 18 inches, or $l=3$ feet, if we take $d=9$ feet, and compute for the different values of m, the values of p, we may derive from them any other values of p, for all diameters of wheels by simple proportion. For the quantity p when $d=9$, our formula becomes

$$p=m . 9{\cdot}33709,$$

and the table will stand as follows:

Table of the velocity of the piston in feet, when the diameter of the wheels $=9$ feet, and the strokes $=18$ inches.

m	p	$9p$	m	p	$9p$
10	93·3709	840·3381	50	466·8545	4201·6905
15	140·0563	1260·5057	60	560·2254	5042·0286
20	186·7418	1680·6762	70	653·5963	5882·3667
25	233·4272	2100·8448	80	746·9672	6722·7048
30	280·1127	2521·0143	90	840·3381	7563·0429
35	326·7981	2941·1829	100	933·7090	8403·3810
40	373·4836	3361·3524			

By means of the column $9p$ we have the value of p for any other diameter of wheel, by simply dividing the number in that column for the required value of m by the given diameter of the wheel; thus, for instance, with a 5-feet wheel, at 20 miles an hour, we have $\frac{1680\cdot6762}{5} = 336\cdot1352$ feet, per minute, for the velocity of the piston. At 60 miles an hour, with the same wheel, we have $\frac{5042\cdot0286}{5} = 1008\cdot4$ feet per minute. In the same way, if we have any other length of double stroke than 3 feet, we have only to take the value of p from the table for the given number of miles per hour, multiply it by 3, and divide it by the length of double stroke in feet, or calling l' the new double length of stroke, and p' the required velocity of the piston in feet per minute,

$$p' = \frac{3p}{l'}.$$

Coming now to look at the Great Western Railway in its more general bearings, we may examine the late reports on its construction, which, published as they are by the directors, have the sanction at least of authority to give them weight. We are sorry, however, to say, that they possess none; they have left the main question as undecided as ever, and present little else but irrelevant matter, or that which contradicts itself. Our inquiry will naturally embrace, first, the reports themselves, and, secondly, the experiments on which they rest.

The first is Mr. Hawkshaw's, and this is so completely set at rest in the reply of Mr. Brunel, that no one would require any discussion respecting it. Mr. Hawkshaw states that at the risk of being tedious, he has endeavoured to develope the process by which he has arrived at his "opinions," because he thinks it better that his report should "partake more of the nature of demonstration, than of mere assertion;" and he then informs us that the Great Western Rail-

way, "has been applauded to the skies as wonderful; it has been derided and run down as little less than nonsensical. Now it is neither one nor the other of these." He has not furnished any "demonstration" of this fact, and is much less fortunate in another assertion, namely, that on coming first on the Great Western line of railway, that which immediately strikes the attention is the "enlarged capacity of all things." We have travelled on that line now four times, but are not aware, from our own observation, that all the things which were on it possessed a large "capacity" than those which we have met on other railways.

Coming next to the report of Mr. Wood, we find it stated that nearly all the experiments upon which it rests for its foundation, were made both by and under the superintendence of other persons, and the mere dressing them up, a purely arithmetical operation, has alone been performed by Mr. Wood. To those who are at all acquainted with that gentleman's knowledge of formulæ and figures, this would be quite a sufficient intimation of what might be expected; but, in addition to this, hardly any of the experiments are given in the report, and no formulæ; and thus the only essential things, from which a right conclusion can be drawn, have been withheld from the shareholders. In the meantime the farce has been played out, and the curtain has fallen.

We shall not stop to notice such mistakes as, that one ton and a half is to one ton and a quarter as four to three; but proceed to the tabular matter in the report, selected from all the records which have been taken of the various experiments, we presume, as that which was most worthy of being laid before the directors and the public, as a fair statement of the capabilities of the Great Western Railway as compared with others; and it should be remembered that Mr. Wood sets out by laying down a rule that, unless his inquiries were conducted in such a way, as to "elicit by incontrovertible and practical experiments, the relative capabilities of the two systems of forming and constructing rail-

ways," it would "not only be a waste of time, but would be attended with perhaps still worse consequences."

The advantages which have been aimed at in the extension of the guage, from 4 feet 8 inches, to 7 feet, and in Mr. Brunel's other alterations, are principally as follows. A greater speed; a decrease of friction, by enlarging the diameter of the wheels; greater stability, by keeping down the centre of gravity, through the body of the carriages being inside the wheels, and not over them, as in other railways. The main objections made to his system, are the increased cost of forming the railway; the greater weight and size of the engines and carriages; the additional friction on curves; the extra cost of construction both in carriages and engines, and the impossibility of a junction with other railways. It is to strike a balance between these that Mr. Wood has produced what he states as "correct and indisputable results."

On the question of speed, Mr. Wood decides that the less powerful engines on the ordinary railways go within three miles an hour of the most powerful ones on the Great Western, and he presumes from this, that the more powerful ones would exceed the best of the Great Western engines; the effective power yielded by the former being apparently much greater than that which is obtained from the latter. This very extraordinary statement is attributed to the resistance of the air, which Mr. Wood seems to think a new discovery in railway matters, although Newton, Robins, Smeaton, Hutton, Dalton, Pambour, and others, have given it in print from nearly two hundred years ago up to the present day, and practical men have all along considered its effects on railways, whilst theorists alone have stated it to be of no consequence. It is twelve months since anemometers were planned, and estimates obtained for their erection at the stations along the London and Birmingham railway, by the writer of this article, at the desire of Mr. Bury, who has contracted for the locomotive power on that line. With respect to the speed of the Great Western engines, in consequence of hose improvements to be expected in all mere mechanical

contrivances, and which the usual engines have been ten years benefitting by, whilst those on the Great Western line are yet insufficiently tried, Mr. Brunel states, that since Mr. Wood's experiments, he has so improved the very engine with which the highest velocity was then attained on those trials, that, all other things being the same, her performance was, and is as follows:—

	Load; tons.	Average speed.	Coke per ton per mile.
Mr. Wood, Sept. 1838,	15·9	38½	2·76
Mr. Brunel, Dec. 1838,	40·0	40	0·90

The decrease of friction in large wheels is admitted as well as other conveniences, although it is stated these can be arrived at with a less guage than 7 feet, and 6 inches is given as the maximum increase on the old width requisite for improving the engines. The weight per passenger appears to be the same with the Great Western and the ordinary railway carriages, although Mr. Wood states they have 1½ tons on each wheel, while the ordinary ones have only 1¼. That there is a greater stability and steadiness of motion in the carriages, Mr. Wood denies.

We have now to examine the tables given in this report, containing the incontrovertible experiments which are presented as affording a foundation for the opinions delivered, and it will be quite sufficient for every purpose of testing their value, if we take those on the deflection of the rails and supports on the Great Western and other railways. These experiments, it appears, were made almost exclusively on the short space of about two miles in the clay cuttings near Paddington, undoubtedly the worst part of the road.

Mr. Wood states that stone blocks afford decidedly the firmest and most unyielding base, and that between longitudinal bearings, the usual sleepers, and the Great Western plan, not much difference of deflection exists. The weight of the engines not being given, we must chiefly confine our observations to the quantity of deflection produced by the

coaches, the weight of which, on one wheel, is as 6 to 5 on the Great Western, compared with other railways.

	Engines. Vertical.	Engines. Lateral.	Coaches. Vertical.	Coaches. Lateral.
Great Western in a perfect state.	·13113	·02453	·10517	·02473
Do. with the piles cut.	·0979	·01047	·06923	·00843
Do. with the transoms cut.	·07743	·00513	·0768	·00353

The above are means of three deflections taken at a single transom, a double one, and mid-way between them. Comparing now the effect of coaches on this and other railways, we have as follows :—

	Vertical deflection.
London and Birmingham, 60 lb. parallel rail, 3·75 feet bearings on blocks	·0261
Do. do. 50 lb. fish belly, at 3 feet bearings on blocks	·03277
Liverpool and Manchester 62 lb., parallel, 3 feet on blocks	·03853
Manchester and Bolton, on longitudinal bearings	·05703
Grand Junction 65 lb., parallels, on blocks, 4 feet bearings	·0301
,, the chair under the rail	·0149
,, the block under the chair	·0714
,, 65 lb. parallels on sleepers	·10293
,, the chair under the rail	·0717
,, the sleeper under the chair	·0511

	Engine.	Coaches.
Grand junction, lateral deflection on blocks, rail	·01615	·01
Do. do, chair	·0200	·0135
Do. do, block	·0053	·0007
Do. on sleepers rail	·0188	·012
Do. do, chair	·0112	·077
Do. do, sleeper	·0125	·008
Do. on longitudinal timbers rails	·02985	·0221
Do. do, chair	·0387	·0265

From the tables in the report whence we have formed the above means, we find that a 60 lb. parallel rail at 45 inches bearing, deflects only ·0261, while a 62 lb. parallel at 36 inches bearings, deflects ·03853, and a fish-belly at 36 inches bearing, and 50 lbs. in weight, only deflects ·03277.

In the 50 lb. rail upon blocks, at the joint chair, there is more deflection than in the middle of the rail, and about three times as much as at a single chair with the weight of a coach; whereas, in the 60 lb. rail, the deflection is more at the single chair than at the joint, but, in this case also, it is least in the middle of the rail with a coach. In the 62 lb. rail it is also greater at the single than the joint chair, and less in the middle of the rail than at the single chair.

In the Manchester and Bolton experiments, the rail deflects more than the timbers at the transoms and joints, but in the middle, the timber deflects more than the rail. With the 65 lb. rails, either on sleepers or blocks, the deflection is considerably more, either with an engine or a coach, at the chairs than mid-way between them; and whilst the rail only deflects ·0301, and the chair which supports it less than half this, namely, 0149; the block which supports the chair deflects five times as much as the chair itself, namely, ·0714. These are called incontrovertible experiments.

In addition to this, Mr. Babbage, no mean authority, who has seen the original records of the experiments, which the report made to the directors does not contain, states in his speech at the meeting of Great Western proprietors, held on the 9th January 1839, that with respect to the increased power required through the resistance of the air, that instead of 15 per cent. being necessary to gain an increase of speed of 3 per cent., it turned out that from the use of the same formula, and the same experiment whence Mr. Wood had deduced the above results, that the increased power required was only as 2 to 1, instead of 5 to 1, as stated by Mr. Wood.

It is astonishing to see what mistaken ideas many per-

sons have entertained amongst the proprietors of this railway. One stated that although the resistance of the air might have been known, yet, it was never taken into consideration at such speed as had now been attained in railway travelling. What, then, becomes of the experiments of Robins and Hutton, which upset the ancient parabolic theory of projectiles, and established the present practical system of gunnery; the deduction of these writers were carried up to velocities considerably greater than that in which air can rush into a vacuum, that circumstance forming one great guide in establishing their results.

Another person wished to know, when such a very great advance had been made by Mr. Brunel in so short a time, by which, with fully one-third less fuel the load drawn by the North Star engine, was increased from 16 tons to 40, at an increase in velocity also; why the same could not be done with all other engines upon narrower railways, and thus an equal effect produced with a much less costly mode of construction. The simple answer to which is, that on the railways with the original guage, the engines have been made gradually more and more perfect up to their present state; whereas on the Great Western, this has yet to be done. Mr. Brunel, in the above improvement on the North Star, has not made any new discovery in the organization of a locomotive; he has only brought its mode of operation nearer to that which is in action on other lines of railway.

Other persons have said, that granting Mr. Brunel does obtain the speed and power he has anticipated, his engines will then do too much, that passengers will never be fouud to assemble in sufficient numbers to fill such heavy trains, and that consequently all the extra cost of the new system will in the end be thrown away. This argument is no more tenable than the others, and throughout the whole inquiry there appears a lamentable want of nearly every requisite for coming to a right conclusion; even the instruments used in the experiments are inadequate for that which they were

intended to shew; of those used to ascertain the motion of the carriages, Mr. Babbage states, that having tried three similar ones of different lengths merely, he could make each of them tell different stories, and whichever he pleased give the greatest result; also that when he tried the very same instrument used in the experiments of Mr. Wood, instead of finding any thing like corresponding measures of the oscillations, his so grossly exceeded those which formed the basis of the report, that they were beyond all magnitude; and after travelling 120 miles in those trials, he came to the conviction that every thing in the shape of an experiment connected with that instrument, must be thrown overboard.

No inquiry, in fact, could have ended more unsatisfactorily than have these experiments on the Great Western railway; and their records, which should, above all things, together with any formulæ used, have accompanied the report, were not published with it. This is the most unfortunate error of all; for as they were chiefly made by other persons, and not by Mr. Wood, they require to be examined, first, as to their correctness as experiments, and secondly, as to how they have been dressed up to produce to the proprietors. In the first case, there might be some little difficulty, but in the second, every proprietor could have judged for himself, and he ought to have had the means put in his hands to do so. Strange to say, too, Mr. Wood has quarrelled with his own report, and declares he made the North Star engine do just the same as Mr. Brunel has done. Why then did he not publish this himself, instead of giving a very different experiment, after placing which in his own report, he blames the directors for sending it forth to the public?

The whole of the proceedings in this discussion serve to shew, as we have before stated, that it is high time some government measure was brought forward to regulate, at least, the general principles of railways; many persons are afraid of this interference with what is justly considered private rights, but to these we would say, that on several

of the leading lines in England, a far worse oligarchy now exists than can be called into operation by any measure of government, thoroughly sifted as it would be in parliament by the numerous members of both houses who are interested so many ways in the right management of these important concerns.

The result of the Great Western discussion is as follows: The unanimous abandonment of the piles; the substitution of a larger scantling of timber and a heavier rail; and the retention of the wide guage and continuous bearings. As far as the railway public are concerned, they will be but little affected by this. The rails are much too light and want depth, and their shape should be the subject of properly conducted experiments. The guage being retained, all the necessary information relative to its efficiency and economy, will, no doubt, in time be made known. The question of longitudinal or transverse bearings is of much less import than is generally imagined. The part of the line on piles between London and Maidenhead, twenty-three miles, if it be retained and kept in good order, will soon set at rest the question of expense in maintaining the way. Thus, then, so far as the public are concerned, all is well; but the effect of this decision on the interests of the proprietors has received no light whatever; there is nothing even to shew that in adopting a heavier rail, there is the slightest necessity also to adopt a greater scantling of timber; and it is extraordinary that a point so easily submitted to experiment and calculation, should have been entirely passed by in the final report to the proprietors.

We have hitherto looked principally to the construction of a railway; there is, however, an equally important point to be considered, and that is, the working of it after it has been constructed. On this will mainly hinge the degree of profit which may be expected; for, let all our previous instructions be duly considered and properly followed out, with such deviations only as may be rendered necessary

by local circumstances; or let a railway be constructed in the best and most advantageous manner, yet it will soon be discovered that, if it is not worked on a sound and effective system, it will turn out a vastly different speculation to what it would be under proper management.

For this purpose every thing should centre in one committee of directors; these may with advantage subdivide themselves into smaller bodies, for particular purposes; all business transacted by these subdivisions being merely preparatory, and nothing being finally concluded till brought before the general body. There should be no boards of direction at each end of a line, but that terminus which is best situated to effectually overlook the whole of the various business, should be made choice of for the seat of government. There should be ample inspection into every department, but it should be inspection only; all orders should come from one committee, and through one general head. It may often happen, and always with advantage, that both ends of a railway may be opened before the middle is finished; still every thing should centre at the governing end of the line, at one point; and the mode by which this government should be carried on, must now be considered a little more at large.

The first question which arises is, by what system can a joint stock company be so managed as to obtain the same amount of alacrity, vigilance, and industry in its service, as characterises the conduct of individuals when acting for themselves, and to combine with these qualities an honest and economical administration. The system of management by boards of directors has stood the test of considerable experience, and, where the proper men are found for directors, this system is admirably adapted to answer the primary object of a board, viz. to deliberate and decide on principles. More information and greater variety of view is brought to bear upon a subject when it is discussed by several men, than almost any individual intellect could fur-

nish; and, as joint-stock companies consist of persons in almost all classes of society, a board composed, as it should be, of individuals holding a large amount of stock, and giving their services gratuitously, for that reason, as well as from a sense of public duty, by embodying various interests, claims and secures the confidence of all.

It is well known, however, that a body consisting of many individuals is utterly unfitted for executive functions. It is admitted as a principle, that executive administration is best and most efficiently exercised by one and one only, and, accordingly, every board, whether of government commissioners, or of joint-stock companies, or of charitable institutions, has some one to whom is entrusted the executive superintendence, and control of that, whatever it be, on which the board exercises its legislative and judicial functions. Connected with this executive are other officers, many or few, exercising a separate jurisdiction over their several departments, and in all details independent, yet held together, for the purposes of combination, by the executive officer.

In the management of railways, such an officer is more especially required where the heads of departments are necessarily numerous, in consequence of the several branches of business into which the working of a railway is divided; where each department employs a considerable number of men, two alone, those of the police and porters, amounting almost to a regiment, and where all are to be brought to act with the precision and regularity of a steam engine. It would be impossible to produce unity of action amidst such conflicting elements, without a close, active, and unremitting personal superintendence, such as may be accomplished by an individual, but can never be effected by a board.

Several attempts at a different system of management have been made by railway companies, but they have not been found to answer. A favourite project has been much

talked of lately, viz. that a committee of three should be chosen from the body of the directors, in which triumvirate should reside all administrative and executive functions, and so much of the deliberative and judicial as relates to the ordinary affairs of the company, and that each triumvir should receive a salary sufficient to command his whole time for the company's service, the chairman receiving a higher remuneration than his colleagues. The advocates of this plan contend, that it would first secure unity of action in the principles of management, with prompt execution in the details, a ready redress of grievances, and remedy, or rather prevention of abuses. Secondly, that it would give the personal responsibility of a few to the proprietors, in place of the collective responsibility of many ; and, thirdly, that it would keep in check the undue power and influence which, under a different system, the executive officers would be likely to acquire.

This view appears more plausible than sound, more specious than solid. In the first place, the triumvirate would monopolize the whole power of the company, and the board would go to sleep. The board of which the triumvirate form a part, would meet too seldom and know too little, to be a match for three men, who would act together every day and know every thing, and who, above all, would enter into debate with the larger body, and vote as directors upon questions affecting their own conduct. It has always proved a thoroughly vicious system to have an executive officer a member (as in many boards he is) of that body, whose orders he is to execute, and to whom he ought to be responsible ; and this applies to the triumvirate.

In the second place, the responsibility of each triumvir would merge in the collective responsibility of the whole board, and men would be exercising a power for which, practically, they could not be called to an account ; for, when the board had confirmed an act of the triumvirate, what chance would the proprietors have to make them ac-

countable? The results of irresponsible authority, it is well known, are jobbing and every sort of peculation.

In the third place, it is not likely that three men chosen out of a body of directors, would be the men best fitted for the situations contemplated. Not only is the number out of which they would be chosen too few to present sufficient of the peculiar ability required, but the selection of the individuals would be rather determined by personal predilections than by their fitness. It would be an appointment to be canvassed for, and the men who would take the most pains to get it, would be just those least suitable for it.

It will be readily seen, also, that under such a triumvirate no really good officer could act. The perpetual meddling with matters they know little about, the jealousy of their authority, and the necessity to be busy in order to give a colour to the notion that they do work, which would inevitably belong to such a body, would disgust an officer who knew his duty and wished to do it, and they would be left to perform the business with none but subordinates. So far, then, from attaining the advantage contended for, a triumvirate committee of management constituted on the above plan, would tend to greater evils than those sought to be remedied by it. The old Navy board, abolished by Sir James Graham, is a case in point: this board was an executive one, and yet subordinate to the admiralty, and the natural consequences followed; they were continually working against the orders they received from the superior board, in order to carry out their own plans, not openly, but covertly; there was, in fact, a constant under current of opposition, from which the business of the country notoriously suffered.

If, indeed, the proprietors of any railway would agree to invest the whole power of management in three commissioners, chosen from the country at large, as the fittest men to be found, making them reponsible to the proprietors assembled in general meeting, and assimilating this trium-

virate as nearly as possible to a government board, more favourable results might be anticipated than from any other plan; but how should any company get three paid commissioners, who are not proprietors, to look sufficiently closely to the economy, out of which a good dividend should arise?

The conclusion, then, is, that the present system of direction is, on the whole, the most suitable for managing a concern, whose nature is commercial, and the end of which is the realising of a profit to the proprietors, upon a money investment. A very important principle, however, is too much lost sight of in the composition of boards of directors. The practice is, for the same persons to be selected year after year, till all sense of responsibility to the constituent body is lost, and the board becomes an oligarchy, of a spirit akin to the old self-elected municipal corporations, the members losing year by year their interest and sympathy in the views and feelings of their constituents, and yet prone to consider them as identical with their own.

For this the appropriate remedy is, a new infusion into the direction, periodically, from the body of the proprietors, and for which parliament has in most cases provided, by requiring a certain portion of directors to retire every year. If the proprietors give common attention at their general meetings, and are careful to select for directors the fittest men, not allowing the re-election of retiring directors to take place, as a matter of course, they will find their interests as well secured under the system recommended, as they are likely to be under any other, namely, one general board, and an efficient executive officer. We should always recommend one thing, which is, that the half-yearly reports should be printed and sent to the proprietors, at least a fortnight before the general meeting.

We shall now proceed to shew what are the duties in the subordinate departments; and the first branch of the office business which we shall endeavour to explain, is the finance or treasury department. It is to be considered an under-

stood thing, that all monies of every kind, whether from calls, loans, interest, fines, sales of property not required for the railway, or from passenger traffic, goods' traffic, parcels, carriages, or cattle, should be invariably passed into the bankers' hands at the principal end of the line: all payments should then be made by checks on the bankers, so that no money whatever, except under the head of " petty cash," should ever be paid from the office: what is called " petty cash" is a running account for postages, carriage, and other trifling disbursements, which are unavoidable; not more than L.10 should be drawn at a time for this purpose; and every item of expenditure should be entered in the " petty cash book:" the clerk having charge of this book and the " petty cash," should count over his balance and produce his book every time he applies for another check.

Checks should be signed by at least two directors, and countersigned by the secretary, and they should not be issued except once a-week, after the meeting of the Board of Directors, except in very urgent cases. Dividends on loan debentures should be made payable at the bankers', at sight, on the presentation of the interest warrants; and, in general, the whole of the cash in the bankers' hands, should be held at the disposal of the directors; and all payments for land, compensation, works, materials, interest, &c., during the construction of the works, should be ordered by the directors at their weekly board meeting, and the whole account of receipts and disbursements properly passed through the company's books by double entry, each head in the ledger being summed up, and a balance struck every six months, in order to present a complete and perfect balance sheet to the proprietors at their general meeting.

The above refers principally to what may be called the " capital account," which is, to shew the receipt of all the company's capital, and its disbursement in constructing the railway, and furnishing it with all necessary engines, car-

riages, waggons, tools, and implements of every kind, to enable the line to be sufficiently worked; when the working for traffic has commenced, another complete set of accounts must be opened under the head of "management;" in this the receipts from every species of traffic on the railway, and from rent or any other receiving source, form the one side; and the disbursement of every kind, for repairing and maintaining the permanent way and works of all kinds, engines, carriages, waggons, trucks, &c., as well as the expenditure for locomotive power, police, porters, clerks, offices, lighting, watering, and every other head, form the other; each head being kept distinct so as to shew at once what money is laid out under any one. The heads of departments should be able to dissect and distinguish every species of expenditure in the minutest manner; the head office only dealing with the respective totals, as they are sent in after being examined and passed.

For example, in the construction department, the weight and price of each item composing carriages, waggons, trucks, barrows, or any other thing which is made there, should be entered separate and distinct, so as to shew first the quantity, weight, and price paid in the aggregate for each article, and secondly, the cost of each carriage, waggon, &c., which has been made, together with their weight. Each carriage of every kind should have all the above particulars entered in a book, an account being opened with each, in which the quantity, nature of the work, time, and price, should be entered whenever that particular carriage receives any repairs; with remarks on the wear and tear of any which may be different in their construction, or in any part of it, together with the weight of all new materials supplied; and on the other side the number and length of the journies which each carriage has performed; for which purpose every one should be numbered; and this is best done by not going consecutively through the series, but devoting a set of num-

bers to each sort of vehicle, so that the number denotes also the class; for instance, the first hundred may be exclusively mails, the second hundred for the first-class carriages, the third hundred for the second class, the fourth hundred for carriage trucks, the fifth hundred for horse boxes, the sixth hundred for goods' waggons, the seventh hundred for earth waggons, and so on; which plan should also be followed out in numbering the clothes and appointments of the police, porters, guards, and plate-layers.

This is more particularly essential in the engineering and locomotive department. In the engineering should be carefully distinguished the expenses for labour, horse hire, tools, new materials for the permanent way, repairs of tools, waggons, barrows, hand-carts, &c., as well as the performance of all the ballast engines, shewing the number of miles run, the number of waggons drawn, the number of cubic yards of earth or ballast carried, and the expenses for coke, oil, waste, and all other articles, together with the amount paid for wages and repairs, which latter should be furnished from the locomotive department; and any repairs done in the construction department should be sent in likewise, in both cases only the gross amount; those departments being able to furnish all the details whenever they may be required.

In the locomotive department it is of the most vital importance to have a most complete and perfect statement of every item composing the disbursements, on account of working and repairing the engines. For this purpose a weekly report should be sent in, which is afterwards to be entered in a book kept for that purpose, and ruled so as to correspond with the columns of the report; this document should consist of two parts, one stating all the items composing the particulars of the performance of the engines, with the attendant expenses in the gross; and the other should shew the minutest particulars of every sum expended in labour and materials, so as to shew in detail what is given in

two columns of the first part of the report in gross. There should be columns in the first part, for each of the following items, viz.

The name or number of the locomotive engine, and the name of the maker.

The description of the engine, her first cost, and repairs prior to this report.

Average speed per hour.

Number of hours at work.

Number of journies.

Length of journies in miles.

Number of miles traversed with load.

Tare or weight of waggons, &c., moved in either direction.

Nett weight of goods moved in either direction.

Number of tons of goods moved one mile.

Tare or weight of coaches moved in either direction.

Number of passengers moved in either direction.

Weight of passengers moved in either direction.

N.B. This may be omitted by establishing an average.

Number of passengers moved one mile.

Quantity of coal or coke consumed in tons, &c.

Quantity of water evaporated in imperial gallons.

Steam pressure.

Average price paid for the coal or coke.

Quantity of oil consumed in imperial gallons.

Cost of repairs in labour.
Cost of repairs in material.

These in detail form the second part of the weekly report, and will be explained farther on.

Cost of fuel.

Cost of oil, tallow, or waste.

Amount of wages for working the engine.

Amount of wages for cleaning, pumping, and coke filling.

Cost of superintendence, and sundries.

Total locomotive disbursements.

Interest on capital.

Estimated depreciation.

Cost per ton per mile of nett goods.

Cost per passenger per mile.

Remarks.

In the second part of the report it shews in detail that which is given in the aggregate in the two columns noted above, the second part of the report being separated into two divisions, one for each column ; for the first of which, namely, the details of the cost of repairs in labour, the columns should contain the following headings, each being ruled for pounds, shillings, and pence.

Date and number of the engine.

Cleaning and adjusting pistons, slides, man-hole door, and packing glands.

Lifting, stripping, cleading, and putting together.

Fitting at carriages, and axle-rod brasses.

Fitting at side rods, keys, liners, brasses, straps, turning crank pins, and keying-on cranks.

Fitting at connecting rods with straps, keys, brasses, and liners.

Lifting apparatus, with eccentric rods, straps, sheaves, forked lever, clutch ring, and all reversing gear.

Frame with hand railing, springs and pins, links, frame ends, with buffers, and foot-board.

Fire box.

Taking out and putting in tubes, and fitting hoops.

Smoke box, blast pipe, and chimney.

Taking off and keying-on wheels.

Coupling bar, drag bolt and plates, cotters, ferrules, and all dragging apparatus.

Pumps, plunger, glands and bolts, clack seats, union and suction pipes, and hose.

Painting.

Boiler.

Tender, with tanks, boxes, and box heads, hoses, brasses,

springs, and pins, carriages, draw bars, drag springs, brake, buffers, and footsteps.

Fire bars and fire frame.

Weigh shafts, slide spindles, and slides.

Guage cocks, and glass water guages.

Pistons.

Cross heads, cross bars, parallel blocks, and bars.

Tools.

Sundries not enumerated.

Total.

Remarks.

The second division of the second part of the report should have exactly the same number and description of columns, only it is headed, "Particulars of the expenditure in materials," whereas the first division was headed, "Particulars of the expenditure in labour;" and the gross total of the first part of the report is all which is entered in the company's general books, and the head office, which rule is to be followed out in every case; the company's ledger only dealing with total amounts, as they are examined and audited; whilst each department is at all times in a condition to furnish every detail in the fullest extent.

Resuming our explanation of the duties in the finance branch. Where the totals as above have to appear, the shares, calls, and deduction for losses, are all registered in this department, which also issues all circulars for calls. A weekly return of sums received for calls, interest, and from all other sources, should be made by the company's bankers, and laid before the committee at their board meetings; each return being regularly entered in a book appropriated for that purpose; and should the company have more than one banker, a book of this description must be kept for each. The calls should be posted from these books to the credit of each proprietor, in a general register of the shares and calls, in conformity with a provision to that effect, generally introduced into the acts of incorporation of railway companies.

A register of the proprietors of the company's shares, and of all the calls paid up on them, should be sealed at each half-yearly general meeting, by the chairman, in the presence of the meeting.

All payments should be ordered at the weekly meeting of the directors, on lists made out previously, and checked in every item, in the proper department to which it may belong; and where any payments are unavoidably obliged to be made between the board days, such payments should invariably be brought forward at the next meeting of the directors, for their approval. Payments for land and compensation are best made through the company's solicitor; all the sums so handed over to him being charged against him as advances, to be cleared off his account from time to time, on the production by him of the proper vouchers from the parties entitled to the money.

Payments for all the contract works during the construction of the line, should be made to the contractors, upon certificates from the engineer-in-chief, or the company's architect, as the case may be, of the sum due to such contractors for the work performed. Advances made to the contractors, which should only be done on the recommendation of the engineer-in-chief, should be charged to a separate account, to be cleared off by future certificates of work performed. Payments for works performed by the company, should be made on the engineer's requisition, and charged to the account of the work. Payments for permanent way materials, engines, carriages, stores, &c., should be made upon a certificate from the head of the respective department that the articles have been received, and that they are of the kind and quality required, and in conformity with the contract.

Advances should be made to the engineer-in-chief and his assistants, for the current expenditure of their respective departments, on their requisition; which advances should be cleared off every quarter, by detailed accounts of

their disbursements, accompanied in each case by the proper vouchers. In the same way, when the line comes to be opened, advances are to be made to the resident engineer, superintendent of police, foreman of porters, locomotive power department, platelayers, &c., on weekly pay-bills, signed by the proper authority; and to the secretary, for the necessary office expenses, travelling charges, &c.; the secretary periodically producing his accounts of these disbursements before the committee of directors, after they have been examined and audited in the proper office.

The general books of the company in the finance department being all by double entry, auxiliary books must be kept for every matter of detail; but the general heads of receipt and expenditure, of which these auxiliary books should present the analysis, ought to be posted in the journal and the ledger. These auxiliary books are to be filled up from the periodical returns sent in by the various departments; and from the certificates of work done by the contractors on the line, during the construction of the railway, as well for their contract, as for their extra and additional works, which, when examined and checked, should all be entered in detail, so that the total money paid for earthwork, brickwork, stonework, laying the permanent way, &c., can at all times be seen, for each contract, and for the entire railway.

In the same way, all the money laid out for the purchase of materials for the permanent way, for stores, carriages, engines, and all other matters whatsoever, should be entered in the general books in one amount for each class, the details being at the same time placed in the respective auxiliary books; and the sums, when certified and paid, should be posted in the gross, to the credit of the contractor, and the debit of the contract in the journal and the ledger, the contract amounts being credited by corresponding debits in the capital amount.

At the weekly meeting of the board of directors, there

should be laid before them the following finance documents: Abstracts of the sums to be paid of every kind, which should be previously checked and examined, and accompanied by all the necessary vouchers, such as certificates, invoices, pay lists, &c.; a general statement of sums received and paid, under all the distinct heads of expenditure during the past week, together with the whole amount paid under each head up to that day, and an account of the disposal of the balance of cash. A detailed account of the weekly receipts and expenditure in the coaching and carrying departments. A monthly balance sheet in the week following the payment of the contractors on the railway; and generally, every document necessary to set forth a complete history of the cash transactions, both as to receipt and expenditure, for the previous week.

When once a correct system is set on foot, every thing will go along with order and regularity; there will only require a slight modification of the routine when the railway is open; for instance, the principal payments will before that period be made to the contractors for constructing the railway, and for permanent way materials, engines, carriages, the construction department, &c., and the receipts will be on the calls and loans; in some of these items a considerable decrease will take place on the opening of the line, whilst in others there will be a final conclusion; after which the receipts for the traffic in passengers and goods, and the payments in the locomotive and carrying departments, and maintenance of the permanent way, together with those to the loan creditors, and the proprietors, will for the future constitute the principal cash transactions of the company. No advance to any officer of the company, should at any time be made, except for a specific purpose, approved by a minute of the committee.

The best plan of paying the money into the bankers' when the railway is at work, is for them to have a clerk in constant attendance at the head office, who should be paid

by the railway company, and to whom should be handed over the proceeds of each train, whether of goods or passengers, as soon as the accounts are completely made up by the company's cashier ; he should also receive, every morning, the cash collected from the out-stations, by the last train of the preceding day ; which cash, on being received by him, is charged to the bankers precisely the same as if paid into their bank ; he transmiting it there in whatever manner they may direct.

Connected with the finance department are the duties of the disbursement clerk, to whom the pay sheets of all the various departments, on which their weekly wages are transmitted, should be sent to be examined and checked ; noting any increase or decrease from the number paid in the preceding week, by a comparison of the current pay sheet with the last. He should be furnished with a list of all authorised additions, deductions, or alterations, in the number and disposition of the men employed in each department, and should make a report of any which he may discover which are unauthorised, and having ascertained that the entries are correct, he should then go through all the calculations, and satisfy himself in each case that the sum which is required in the pay bill is that which is due from the company.

The weekly arrangement for paying the whole of the men must be fixed according to the day on which the board of directors meet, in order that the whole may be submitted to them previous to the money being paid ; for instance, suppose the board of directors meet on Thursday, then the week's pay bills should be made up to the preceding Tuesday night, and sent up to the principal office by the last train ; on Wednesday the disbursement clerk goes through the examination of the whole ; on Thursday they are laid before the directors, who order the necessary payments ; on Friday the money is transmitted to the various stations and paid ; and on Saturday the various pay sheets, which

were in each case sent with the money, are returned, with every man's signature opposite to the sum which he received; when this is ascertained to be done, the disbursement clerk should incorporate the whole into a separate disbursement book for each department, with a detailed abstract and analysis, together with a notification of any increase, decrease, or other alteration, and a reference to the authority for such change, with any other remarks which may be necessary to render, in each case, a full and complete history of everything connected with the transaction, without the intervention of any other explanation than what is afforded by the books themselves.

The principal books necessary in the finance branch of the office, will be the cash book, Excequer bill book, if any money is invested in Exchequer bills; journal, general ledger, bankers' ledger, day-books for each call on the proprietors, shewing what is paid into the appointed banks on each call respectively; petty cash book, general abstract of receipts and payments, weekly abstract of disposable funds, weekly abstract of the bankers' returns, shewing their weekly receipts on the calls; and, lastly, the book of half-yearly accounts.

Of these books the following are the only ones which require explanation. The day-books for the respective calls on the proprietors, should each shew in columns the number of the receipt given, the date of payment, the name of the proprietor, the number of the register, the amount of shares, the sum paid, and the interest, if any, the top of each page being headed with the number and amount of the call.

The general abstract of receipts and payments, should shew on the left-hand page, the money received on each call, in three columns, the first being headed, "Last statement," in which is brought forward the total sum in the preceding account; the second headed, "Receipts since," and the third, "Total to this date;" and to the left of these three

columns should stand, from the top of the page and going downwards, one under the other, the words "first call," "interest;" "second call," "interest;" and so on for each instalment. Opposite to each call, in the three columns above described, should be placed the sums respectively paid on that call, and opposite to each word "interest," should be placed the interest received on that particular call which is above it. Under these should in like manner be shewn the receipts derived from any other source, such as interest on Exchequer bills, and bankers' balances, property resold, fines, rents, &c. &c. On the right-hand page should stand the various payments, whether on account or otherwise; the respective heads of expenditure being on the left of the page, one under the other, and three columns being to the right, headed, as before, "Last statement," "Payments since," and "Total to this date." When the two sides are totalled, if to the right-hand side is added the "balance as per weekly statement of Exchequer bills and cash," the two pages must correspond in amount, unless there is an error in the work.

The weekly statement of Exchequer bills and cash should be a short broad book, if there are several bankers with whom the company deposit cash, and should be ruled in vertical columns; the left-hand column should be headed, "Date of last statement," the next "Exchequer bills," the next must have a heading divided horizontally, on the top being "cash," and on the lower part, the name of all the banks; a column for pounds, shillings, and pence, being continued down for each. On the right of these three should be a column for "Petty cash," and lastly, one for the "Total of Exchequer bills and cash." The first horizontal column or row, will then be filled in with the "Date of last statement," and the sums due under the respective heads given. The next horizontal column should shew the "Receipts since last statement," these words standing under the date of that statement which has been filled in. The

next horizontal column should shew the "Total receipts to this date," the next, "Payments since last statement," and the last, "Remains disposable."

The weekly statement of receipts as per bankers' returns on calls, is made up from those returns, which should be sent in weekly from each bank; shewing the number of the receipt, the date of payment, the name of the proprietor, the number of the register, the number of shares, the sum paid, and the interest; and it is from these the day-book of calls is made out. The statement of receipts should have each banker's name in the left-hand column, one under the other; and opposite their name should be entered the sum "received to," with the date of the last statement entered underneath; the next column should shew the "interest;" in the next the returns for the week should be entered opposite each banker, heading the column "weekly returns:" in the next, the "interest" for the week from each; then "total to," with the date of the present statement; and in like manner with the others, distinguishing "call" and "interest." When these are all totalled, if to the sum of the last column is added what is due on the shares yet unpaid, the gross amount should exactly agree with the total of the call.

Paying calls in advance is a measure often resorted to, in which case it will be convenient to send circulars to those proprietors who have done so, every six months, with a debtor and creditor's account, shewing the interest due to them; which may be paid at appointed bankers, on the production of the circular.

The next department to be explained, will be that of minutes and correspondence, which forms a branch in the general office. The duties of the clerks will consist in entering the minutes of the proceedings of all the various committees, boards, and sub-committees; making fair copies of all documents, letters, or orders which require to be transmitted to other parties; making fair copies of all letters for

the secretary's signature; and if there is more than one clerk in this branch of the office, which would be the case in those railways that from their magnitude may be called first-rate, the principal one should have the charge of all letters received, which should be alphabetically indexed in a book, and put away under their respective heads and departments, according to their dates; for instance, all letters that come from the engineer's department should be put away by themselves, under the head of "Engineers," or "Engineer-in-chief," as the case may be; others, under the head of "Solicitors" "Bankers," "Landowners," "Directors," "Contractors on the line," "Contractors for rails," "Contractors for blocks," and so on for all other heads; having also a "Miscellaneous" class for those which fall into no other, and yet are too insignificant to have a class made for them; noting, that as all those which have relation to the construction of the railway will, to a certain extent, be of a more temporary nature than those which are connected with the working of the line, and the maintenance of the railway, all these latter should be kept separate by themselves. The index should have columns for the name, digest of the contents, head under which the original letter is placed, name of the person to whom the letter is sent, either to report on it or to carry it into effect, and the date of transmission. The orders of the committee should be written on the letter, and across the digest in the index.

In like manner, copies should be kept of all letters sent from the office, and be put away similarly to those received, under their different heads and departments. In the same manner they should be alphabetically arranged, indexed, and placed according to their dates. For this purpose pigeon holes are the most convenient things for current use, periodically clearing them out, say once a month, and packing both the letters received and those sent, in bundles between two pieces of stout pasteboard; all of them being

first folded to one size and properly headed. All these bundles should in every case be correctly tallied, both as respects the subject of their contents, and the dates of the first and last letter. The index of letters sent should have a column to note if copies are transmitted to any other parties whom they may concern. Rough copies of all minutes of committees should be made out by the secretary, as the person who attends the committee can word the minutes more in accordance with the feelings of the directors than any one can do who is not present at the discussion. All decisions of committees which have to be executed should be entered in a book of agenda, and marked off as done. Standing orders should be entered in a separate book. The index to the minutes should be as full as possible; and when they order any thing to be done, the minute should be indexed both with the name of the person and that of the thing ordered. Memoranda from the secretary or manager to the various heads of departments may conveniently be sent from a printed book, with a margin for a counterpart, on which the answer, when received, may be written across.

In this branch of the office should be kept all printed forms, papers, and documents of every kind connected with the general business of the office, during the construction of the line; together with blank forms of returns of all sorts, blank tenders for the various kinds of articles that are in constant use, reports of general meetings, handbills, circulars, advertisements, &c. &c.; and in every case one of each kind should be pasted into a blank book kept for that purpose, so that every printed document can be at once referred to, for which purpose they should be invariably numbered in a consecutive series, by the printer, in one corner. With respect to advertisements in the newspapers, the easiest way to keep them ready for instant reference will be to order two copies of each paper, cutting the advertisements out from one, and pasting it in a blank book, on the margin of which, opposite the advertisement, should be

written the name of the newspaper, and the date when the advertisement was inserted. The other paper should be filed and kept by as a full identification of the transaction. The more compact and systematic every arrangement connected with papers and documents of all kinds is made, the more satisfactorily will the business of a large railway company be conducted ; and without this arrangement, accompanied by constant care, method, and regularity, every thing will in a short time be so involved in almost inextricable confusion, that in addition to its becoming next to impossible to find any document which may be wanted, some will be lost, others mislaid, others defaced, and there will be no end to the trouble incurred.

We now pass on to the police department, which is of so much importance on a railway. There should be printed instructions issued to each inspector, and the superintendent ; and also general instructions, embracing all the men in the company's employ ; such as police guards, porters, overlookers, platelayers, enginemen, and firemen ; and every person in the service of the company, should be placed in one or the other of these classes. For instance, switchmen and gatekeepers should always be policemen ; and office-keepers, messengers, lamplighters, turncocks, carriage cleaners, &c. should all be on the porters' list, so as to be available at all times when required to assist in dispatching either goods, or passengers' trains ; engine cleaners should be placed on the list of firemen, and so on of all others ; for which purpose there may be two rates of pay in each class, besides that assigned to the leading men.

The general printed regulations for the whole of the men in the company's employ, should state that each man must devote his whole time and attention to the company's service, and that he must reside and serve wherever he is required, but that in the instance of his being transferred from one station to another, his goods and family will be carried on the company's waggons free of expense. He must, on

all occasions, instantly obey every order he may receive from those persons who are placed in authority over him, and strictly conform to all the existing regulations; and no man, on any occasion, or under any pretence whatsoever, should be allowed to receive money from any person travelling or sending goods by the company's trains. Each man should be paid weekly, at an appointed time and place; and any debts which he may have contracted, upon his receiving orders to discharge them, should be forthwith paid, or in default, the requisite amount should be deducted from his salary.

No man should leave the company's employ without giving one week's previous notice of his intention; and except in cases of misconduct, the same rule should be observed by the company towards their men; if this regulation should not be attended to by the men, they should in each case forfeit their pay for one week; to accomplish this, every man should be kept one week in arrears; and in like manner, if the company discharge any men without the regular notice, they should be entitled to one week's additional pay. Every man who may either be dismissed from his situation or resign it, must, before he quits the company's employ, deliver up all the articles of dress and appointments which may have been supplied him; and if any of these articles should be found to have been improperly used, or damaged, a deduction from the man's pay should be made, sufficient to repair the damage, or, if the circumstances of the case require it, to furnish a new article.

The pay of any man who is sick or absent without leave, should be suspended, for a special order of the committee on the case; but if sickness is clearly ascertained to be the cause, his pay should be continued for a time proportioned to his situation and character. Every man should clearly understand that he is liable to instant dismissal for disobedience of orders, negligence, or other misconduct; that no instance of intoxication can ever be overlooked, and that

in this case, besides being dismissed from the company's service for this offence, the party is liable to the usual fine by a magistrate. Any one who is guilty of incivility or rudeness to the passengers, should be severely and instantly punished, and all should be held liable for any damage occasioned by their negligence ; and they should be enjoined to appear, when on duty, in their regular uniform, and in a proper state of neatness and cleanliness.

On their first appointment every man should sign the above rules and regulations ; and for this purpose a form should be filled in at the bottom, by which he binds himself to observe and obey them. The heads of departments should be authorised, in the company's bye-laws, to make rules for those under their orders, subject to the approval of the board of directors, which should be printed and given to the men to whom they relate, with a copy of the general regulations on the other side. For the punishment of small offences, fines may be advantageously inflicted, the produce of them going to a fund for the sick, or to give premiums for marked instances of good conduct ; and a proper book should be kept, shewing the character of every man in the company's service, in which should be recorded all instances of good conduct, as well as bad ; and whenever a complaint is made against a man, this book should be consulted, and he should be allowed the benefit of former good conduct, on the principle of even-handed justice ; this would cause every man to exert himself so as to attract notice, and thus lay up a good character in store, upon which he may draw when he has imprudently committed a fault.

The whole of the men on the company's permanent establishment should be identified by a number on their collar ; and a neat uniform should be selected, which should be supplied by contract. The superintendent of police should have two suits annually, including boots and hat, and a greatcoat every two years. The inspectors, one body coat, two pair of trousers, two pair of boots, and one hat

every year, and a greatcoat every two years. The guards, two frockcoats, two pair of trousers, two pair of boots, and one hat, with a gold or silver band, according to the lace selected for the general uniform, every year, and a greatcoat, with a cape, every two years. The upper guard should be furnished with a japanned leather cross belt, having an ornamental buckle; by this belt he should sling his timekeeper, in a small leather box; and the one who takes out the most conveniently timed train should regulate the out-station clocks every day; for which purpose a table should be made out for each station, shewing the difference of longitude in time to be allowed, respectively. The police should have one body coat, two pair of trousers, two pair of boots, one hat, and one stock, yearly, and a greatcoat and cape every two years.

The porters and bank-riders, if any, should be allowed two jackets, two pair of trousers, two pair of laced boots, and one cap annually; and the platelayers and overlookers, one cap; which they should constantly wear, under penalty of a fine. Each man who wears the company's uniform, should be furnished with a button-stick and brush, which he should ever afterwards make good when worn out; and he should be bound at all times to keep his clothes in repair at his own expense. Before a man receives an appointment of any kind, the most rigid inquiries should be instituted into his former employment, and present character; and when he is either engaged or discharged, a notification to that effect should be sent to the party recommending him. All the police should of course be sworn in as constables before a magistrate, and should each be supplied with a pair of handcuffs, and a staff; those stationed at the booking offices and gates of the principal station, should have their staffs about five feet six inches long, and tipped with brass at the bottom.

In addition to the above general regulations, which apply almost equally to all, there should be printed instructions

for several of the classes as well. The superintendent of police should be bound to reside in the house provided for him, and he should be held responsible for the general good order and conduct of all the men under his charge, for which purpose he should take every occasion of making himself well acquainted with the conduct and character of every man under his orders, by frequent personal intercourse; endeavouring by every means in his power to detect any irregularity of conduct, taking care that all the orders and regulations issued from time to time are promptly and strictly obeyed, and giving clear and precise instructions to insure the correct performance of each man's duties, he being held responsible in all cases that they are properly understood. He should furnish a daily report of occurrences; detailing every instance of neglect, whether culpable or not, irregularity, or disobedience; stating also every complaint which has been made to him; and should the circumstances of the case be of a nature to require it, he should at once suspend the offender, or take whatever other precaution he may think necessary. He will also have to examine the weekly pay lists prior to their being sent into the finance office; the men should be paid under his especial superintendence, and he must see that every man's signature is attached to his amount, and that in every instance, all possible checks are instituted to insure correctness; and he, with every other person who receives particular printed instructions, should sign a declaration at the bottom, binding themselves to observe and obey them, as well as the general printed instructions.

There should be one inspector at each out-station, and his instructions should state that he must reside wherever he is appointed, and attend such hours as may be required. He should be directly responsible to the superintendent, from whom he should receive all his orders and instructions, and to whom he should make a daily report of all occurrences on his district; making known, without any delay,

all neglect of duty, disobedience, or misconduct, on the part of the men under his charge; and in every case of complaint against a man, he should communicate the particulars, without the least loss of time, to the superintendent, sending the offender to head-quarters if the case should require it, with as little delay as possible. The limits of his district should be clearly defined; and it should be his especial care that all the orders and regulatious which may be given out from time to time, are promptly and strictly obeyed, throughout the whole extent of that part of the railway committed to his charge. He should keep a journal, an extract from which should go daily to the superintendent, shewing for each train the hour of the train, number or name of the engine, name of the upper guard, when the train was due, when it arrived, how much before or after its time, the cause of delay, the number of each kind of carriage in the train, and the number of spare ones, the number attached or detached at his station, and the hour when he visited his district.

He should be in attendance, if possible, on the arrival of every train at his station, and not leave it till the train is gone, and if unavoidably absent, he should appoint the best man he has under his orders to act in his room, who should be denominated a sergeant, and have additional pay; he should receive from the foreman of the porters, or the clerk of the station, all luggage which may be given him, for the safe custody of which he must be considered responsible; he should have charge of the carriages, waggons, trunks, and all the other moveable property belonging to the company on his district. He must keep the necessary pay-books for the police at his station, making out the weekly pay-lists, comprising the names and the sums due to all the policemen of his district, and forwarding them to the superintendent; and he is to report to him any thing whatever which occurs or seems amiss in any department as well as his own; and he will be held responsible for the mainte-

nance of good order, and for the observance of the bye-laws, and all other rules and regulations whatever; and to enforce this, he should have power to take into custody any of the company's servants, as well as strangers, should the circumstances of the case require it, although, as the company's servants must be always known, and their attendance secured when wanted, it would only be in an extreme case that a necessity could exist of arresting them.

He should take care that every proper regard is paid by all under his orders, to the comfort and convenience of the passengers, in affording information, assistance with their luggage, &c., by pointing out to them the proper persons to apply to; and he should strictly enforce civility and respectfulness of demeanour on the part of the men under his directions, setting an example himself in these respects, and reporting all deviations from this line of conduct by whoever they may be made. He should regulate the egress and ingress of the passengers to and from the departure yard, and the coaches which bring them or convey them away, taking care that no person is admitted outside the proper inclosures, till the train has stopped at the station, and the proper orders are given; and he should render every assistance in his power to the clerks, foremen, porters, and guards; supplying as speedily as possible any wants which they may communicate. He must also direct the most vigilant attention to the switches and the gates at the paved crossings, reporting to the superintendent each time he visits his district, whatever he may observe amiss.

He must pay the weekly wages to each man in the presence of the station clerk, obtaining each man's signature to its amount; also keeping an exact account, according to the prescribed forms, of all articles and stores sent for the use or consumption of the police in his district, from the store department, for all of which he must be considered responsible, rendering an account of stock (at stated periods, to be determined by the store-keeper) to the superintend-

ent, where they ought to be embodied in one account, registered, and a copy sent to the store-keeper. He should send all luggage or other property found on his district to the superintendent directly it is discovered, together with the fullest particulars, specifying when, where, and by whom found. He should have charge of the whole of the offices, buildings, carriages, waggons, and all other moveables at the station. In the most open part of the office, he should affix a list of all the men under his orders, with their respective weekly wages.

The police, switchmen, and gate-keepers, should receive their orders for each post from the inspector in writing, distinctly defining their respective duties ; the switchmen should be thoroughly drilled into the mode of moving the switches in the most perfect manner, and on no account entrusted with the sole charge of them 'till it is clearly ascertained that they are thoroughly conversant with their regular movements ; and also that when the eccentrics by which they are opened and shut get out of order, that they can set the switches in each of the required positions with a crow-bar, with which implement they should all be provided. The gate-keepers should also be instructed in a proper method of turning the red and white light in the correct situation, to shew either along the railroad, or the common road, as the case might require, should the machinery get out of order by which it is usually turned. Each policeman should be instructed to place his box, which should turn on a pivot, so, that while protecting himself from the weather, he should be enabled to see along both parts of the line ; and the superintendent or inspector, when he in the first instance places the men in their various stations, should select those spots, particularly in curves, which will enable the man to see the greatest distance in either direction along the railway ; by attention to this point fewer men will be required.

Every policeman, switchman, and gatekeeper, should be

provided with two small signal flags, about two feet long by one foot broad, each fastened at one end of a small staff about five feet long; which flags should be used in the following manner: The exhibition of the white flag indicates that no impediment exists to the free passage of the railway, and the red flag, on the contrary, shews that danger attends the passage of the train, the engine of which ought then not to advance beyond the place where this signal is shewn. When the state of any part of the line requires the speed to be slackened, the policeman should point with his red flag to the rails at the commencement of the unsafe part. In order still farther to prevent accidents, the policeman should station himself at some distance from the precise point of danger towards the advancing train; and should danger exist on both lines, and two trains be expected, if he is not able to call assistance, he should be provided with a larger flag on a seven-feet pole, pointed with iron at the foot, and he should fix this in the ground some distance on one side of the danger, and place himself on the other side. The fixed flag should have an outrigger on the top to keep it across the railway. The policeman should stand on one side of the railway when shewing his signals, and hold his flag-staff across the railway, the heel being on his breast, and the staff sloped upwards at about an angle of 45 degrees till the train has either passed or stopped as the signal required. The red signal may also be shewn when the policeman desires to communicate any intelligence to the guard, but the trains should not be stopped for this purpose except in cases of urgent necessity.

Each policeman should also be furnished with a hand lamp, having a good lens in the front, which should be capable of exhibiting at pleasure, a white, green, and red light, by shades of those colours turning round by hand; the lamp should fix to his side by a waist-belt, and on the approach of a train, the white and red lights form the same signals by night which the white and red flags do by day; the

green light may be used to indicate that caution is necessary, and that the speed of the train should be diminished. These day and night signals should be shewn by the switchmen and gate-keepers, as well as by the other policemen.

The number and position of the policemen must depend entirely on local circumstances, such as the nature of the curves and other matters, which can only be determined on the spot, but in the first opening of a railway it will be much better to have too many than too few. From one to three miles should be the limit, except at the stations; and if the trains work in the night as well as the day, a double quantity will of course be necessary, the night and day relief being so arranged as to vary every day, one man, for instance, taking sixteen hours one day, say from six A.M. to two P.M., and again from ten P.M. to six A.M., while the other only has eight hours, say from two P.M. to ten P.M., and this alternated the next day, or by any other means which will bring about an equality of labour and fatigue. An inspector's district may vary from five to ten miles, according to the nature and extent of the traffic, which must in all cases define these lengths, and point out where there is a necessity for a station.

The police, when placed on their post, on first coming to their stations in the morning, should immediately walk the whole length of their beat, in order to see that the line is perfectly clear, paying the most particular attention to that line on which the first train comes. And they should act by pairs; thus in a line of railway leaving any town in a northerly direction, the policeman on the first beat, going out of the town, should come on at the south end of his beat and walk north, whilst the second policeman should come on at the north end of his beat, and walk south; the two meeting where their beats join, and communicating to each other their observations on the state of the line; and this plan should be continued throughout the whole length of the railway, except, of course, the gate-keepers and switch-

men, who are fixtures. The police should meet in the same manner to relieve each other to meals. In case the policeman by any accident should lose his signal flags, he should intimate any danger to a coming train by standing in the middle of the railway and extending both arms with the hands wide open.

In case of any obstruction, which the policeman may find that he is not able himself to remove, he should summon the nearest assistance as speedily as possible, if necessary, referring the party for remuneration to the inspector of his district, to whom he should immediately report all the circumstances of the case, together with the name of the persons through whose neglect the obstruction was caused.

The forms necessary in the police department, are the following: The inspector's daily report, containing, in columns, the name of every offender and his offence, the name of men sick, and the name of those absent with leave, together with a large column for the respective particulars in each case, in which should be stated how the posts of men absent either with or without leave, are supplied; the heading to contain the name of the station and the date. At the bottom, should be noted every remark and occurrence, on all subjects connected with the state of the line, or the general interests of the company. These should be embodied daily in the superintendent's report to the secretary, which is in the same form as the inspector's, except that it has one additional column on the left hand, both in the upper and the lower part, for the name of the station.

The weekly pay-bills, which should contain columns for the men's number, name, and occupation; the time for which pay is due to him, the rate of pay, the amount in full, the amount of any stoppages, the nett amount due, and the signature of the party receiving the money. The heading should contain the name of the station, and the date of the last day of the week for which the pay is due; the whole signed by the inspector. A weekly return of absen-

tees whose wages are suspended, containing, in columns, the number, name, and occupation of the man; the place at which he was stationed, the cause of his absence, the number of days which he was away from his post, the amount of his pay suspended, in what manner his post has been supplied, and a large column for remarks. This should be sent in by the superintendent from the inspectors' reports, which should daily be transferred to this return, and the money added. A weekly return of punishments, stating the number, name, and occupation, of each man; the nature of the offence which has been proved against him, the nature of the punishment inflicted, and the name of the person by whom the complaint was investigated, and of the person who ordered the punishment. And lastly, a printed form for application for leave of absence, stating the name, number, and occupation of the man, the time for which he solicits leave, the plea on which he solicits it, and the proposed method of filling his post in his absence, and an empty column for the reply. This should be sent daily to the superintendent, who should write in the column for the reply, the word Yes, or No, after which it is returned to the inspector.

Files will be found very useful, hung up round the police office. On these files all current matters of reference should be put, each being tallied in legible characters on the pasteboard; such, for instance, as inspectors' reports, memoranda answered, memoranda to be answered, luggage notes, lost property notes, inquiries for lost property from other railways, (a file for each railway,) absentees, punishments, orders for transmissions, and many other useful documents, which, by means of these files, will always have a place, and without them would be in constant danger of being lost, as well as exceedingly difficult to be got at when wanted. The files should be periodically cleared off, and the papers properly tied up and tallied, and deposited in a place of security, which should be an iron chest.

The books necessary in the police department are the following: The alphabetical register, containing the number, name, age, and occupation of the whole of the men on the police establishment; their height, the date of their appointment, the date of their being sworn in, the date and cause of their leaving the company's service, the name of the person who recommended them, and a large column for remarks; and on the opposite side of the book, their clothing account should be placed, having a separate column for each of the following articles, namely, greatcoat, body coat, trousers, hat, cape, stock, button-stick and brush, hand truncheon, long truncheon, boots, lanthorn, strap, handcuffs, rattle, hand-signal flags, ground-signal flags, and crowbars. This last article only applies to the switchmen. At one end of this book there should be a complete list of the men by their numbers. This list need only contain the numbers, and the men's names.

The lost property book, which should contain columns for the date, number of the train, number of the carriage in which the articles were found, or, if elsewhere, it should be stated, the description of the article, the name of the man who found it, remarks, when claimed, by whom claimed, mode in which the claim was substantiated, the person who allowed the claim to be correct, and the signature of the party receiving the article claimed, with their address. In some railways, it is usual to allow the articles in found this manner to remain twelvemonths, and if not owned at the end of that time, to give them to the porter, or other person who found them, to encourage honesty. But a better plan would be to sell them by auction at the end of that time, and deducting from the amount of the sale, the sums paid by the company for luggage lost, divide the remainder equally amongst all those who have brought any article forward.

The pay-book should contain the number, name, and occupation of the men; the number of days' pay due to

each, the rate of pay, the total amount, the amount of stoppages, the nett pay, and remarks. There only remains now the store accounts. These consist of the goods-received book, which is in fact the journal. In this is entered every article directly it is received. It should contain the date when the article was received, the person from whom it was received, the quantity and description of the article, and the folio in which it is entered in the ledger ; in which book each description of stores should have a separate account opened ; debtor on one side, and creditor on the other. On the debtor side should be the date of the reception of the article, the person from whom it was received, the folio of the journal from which the entry has been made, the number of the requisition-note by which the article was drawn from the store-keeper, the quantity and description of the article, and a column for remarks. On the creditor side should be the date of the delivery of the article for use, the name of the party to whom it was delivered, the quantity and description of the article, and a column for remarks. This book should be balanced every quarter ; the quantity on the creditor side being taken from that on the debtor, shewing what remains in store. These remains should be entered afresh on the debtor side, in the quantity and description column. And in the column for the person from whom it was received, it should be stated as a balance. All stores received from any other person than the store-keeper should be kept detached from those which he has supplied.

The same description of form and books, with the exception of the lost property book, will be necessary for the porters' department ; the foremen of the porters at each station, taking the place of the inspector of police ; and the head foreman at the principal station, that of the police superintendent. There will be required, however, two additional books, namely, the coach-repair book, in which all the repairs to every kind of vehicle in the coaching department should be entered ; and the waggon-repair book, in

which similar entries should be made in the goods' department. These should contain the date, the number of the notice sent that repairs were required, the number of the coach, horse-box, truck, waggon, &c., distinguishing the class of the coach, the description of repairs done, the manner in which the vehicle got damaged, or in the case of additions or alterations, this should be stated in the room of the above; the date when the vehicle was sent to the workshop to be repaired, the name of any tradesman or contractor, if the vehicle has been delivered to them for repair, the number of days' time employed in the repairs, reduced to the time for one man, the weight of ironwork used in the repairs, the number of superficial and cubic feet of timber used, the name and description of any other articles used, the total sum charged for the repairs, the description and price allowed for any partly damaged articles that have been replaced, and the time when the vehicle was delivered at the station in a finished state.

The duty of the porters should consist in keeping all the various carriages and waggons in a clean and proper state. Particular men should be appointed for each class, so that they may become expert in their business. It should be their duty to attach and detach the carriages, and other vehicles, to and from the trains; the foreman at the principal station seeing that each train, to the required number of carriages, is made up at least half an hour before its departure; that all the carriages are properly coupled, and in a perfectly clean and neat state, both inside and out; that the proper number of break carriages are in their appointed places; that the requisite number of mails are attached; and that horse boxes, trucks, and spare carriages, are in readiness to any required extent, and in their proper places; with all the necessary appurtenances; and that the luggage vans, and the requisite steps or ladders to load them, are in readiness. In the same manner he should see every thing prepared for the arrival train, using every means to

facilitate each passenger receiving his or her luggage in as short a time as possible, and that care is taken not to injure it, enforcing in all cases, attention and civility to every person who has arrived by the train. He should appoint a proper person to search the coaches, taking every thing which is found, either in them, or in any other place, to the superintendent of police, and giving it into his charge, except when the articles are found near the departure train, when he is first to cry through each carriage in the train, the nature of the thing found; opening every coach door, if the time for the departure of the train will admit of it; and if no one can describe the article, so as to establish himself as the owner of it, he should then give it in charge of the police.

When the passengers have left the station, he is to see the carriages uncoupled, and cleared off the arrival line, to the respective places appointed for their reception; and either him or his assistant should attend in a similar manner in the goods' station, appointing sufficient men for the cranes, and taking especial care that the waggons are loaded in proper time, and in the manner pointed out by the person whose duty it is to do so. He is to see that the offices are kept in a proper state of cleanliness, and that the requisite number of fires are lighted in the morning, and carefully put out at the proper hour, unless the offices are worked night and day; and generally he should consider himself responsible for the good order, efficient condition, and cleanliness of the station, and all the buildings on it, together with every vehicle in use.

At the out-stations, the foreman should have all his porters in readiness before the arrival of the train with the passengers' luggage as near to the line on which it is to arrive, as it can be conveniently got, always keeping it under cover. When the train has come in, one man should go along it, and call out loudly the name of the station at each coach door; whilst the rest use every exertion to get the

luggage which is going forward, put safely and quickly in the required place, which should be pointed out by the guard; and also that the luggage of those passengers who are going to leave the train, be delivered to them as quickly as possible, and that civility and attention be at all times shewn to them. He should have spare coaches ready, if he finds the passengers about to join the train are numerous; and should take care that all horses and private carriages are embarked and placed in the most convenient spots for attaching to the train. In like manner, with the goods' train, he should see that every thing is in perfect readiness to attach the waggons going on, and detach those which may come off, and that efficient tarpaulins are securely fastened over those goods which may require them.

In all the stations, proper men should, as much as possible, be appointed for all the different duties of the details, such as office messengers, fire lighters, office cleaners, platform cleaners, carriage cleaners, horse box, truck, and waggon cleaners, lamp trimmers, turn cocks, &c. Each station should be plentifully supplied with water, to wash the various vehicles, and with good drainage to carry off the water.

The foreman of the porters at each station should always be informed if any engine is going to be sent along the line, out of the usual times of the trains, which he should indicate to the plate-layers at work upon the road, by hanging a signal on the last carriage of the train which precedes the unusual engine. This signal may be a hoop about two feet in diameter, covered with canvass, and painted red: and at the arrival of any train, he is to see if this signal is attached to the last carriage; and if it is, he should keep all the men under him on the alert, till he ascertains their services will not be required on the arrival of the unusual engine. A red light by night should be used to indicate the same thing.

The foreman of the porters should have entire control over the guards as well as the porters, till the starting of

the train; but he should not interfere with their stowage of the luggage in the passenger trains, except he sees a violation of the standing orders, which, if not immediately altered on his pointing it out, he should report to the proper authority. He should also have charge of all the stores in the coaching department, and those necessary for keeping the carriages, offices, and stations, in a fit state of cleanliness, and for lighting the station with oil or gas, as the case may be; and if the latter, he should keep a weekly register of the gas meter, in a book allotted for that purpose. He should also see that the roof and carriage signal lamps are in proper order; and he should direct the police to make any necessary signals with their flags or hand lamps, in case of any danger to an approaching train. He should keep files, similar to those recommended for the police, in his office, properly distinguished for all the papers which are in current use, so that every paper has an appointed place.

The duties of the guards should be very clearly defined, and printed instructions given them in all cases. There should be two guards to each train, an upper and an under one. The upper guard should sit on the last carriage of the train, with his face to the engine; and he should be furnished with wire spectacles to protect his eyes from the ashes constantly thrown out by the engine chimney, till some means are found to remedy this unpleasant defect. The under guard should sit on the carriage next the engine, with his back to the engine. By this means each guard has constantly before him all the carriages in the train, except the one he is riding on; and they can both communicate with each other by signal. Proper boxes to protect them from the weather, should be fixed to the carriages on which they ride.

The under guard obeys all directions which he may receive from the upper, and both should reside wherever the arrangement of the trains may render it necessary. The

upper guard of each train should receive his instructions from the head station clerk, to whom he should report when the train is ready to start, and from whom he should receive his way bills and passes of every kind, for which proper portfolios should be provided, with locks and keys, having divisions in them for each station ; the papers for every station should be made up in one parcel and sealed. He should make known whatever is wanting to the head station clerk, the foreman of the porters, or the inspector of the police, as the case may be ; receiving his orders to depart, and his papers from the head station clerk, and any other necessary directions from the foreman of the porters, except in the stowage of his papers, parcels, and baggage, of which he should have the sole direction.

The train, when once started, should be under his entire control, and the passengers and their property under his protection ; and he should be responsible for the safety and regularity of the whole, notifying to the engine-man when he is going too quick, or too slow, and reporting whether he increases or lessens his speed in consequence, that due inquires may be made into the reason for the irregularity; this notification he should make through his under guard, by signal, without leaving his place ; for instance, his right hand extended, may indicate that the train is going too slow; and his left, that it is going too fast; and either arm held perpendicularly over his head should signify that the train is to be instantly stopped. Whilst making this signal, he puts on the brake with the other hand. He should not repeat the signal that the train is going too slow, except after a lapse of some minutes, as the engine-man may have good reasons for proceeding at a cautious rate, which the guard may not know, and which might render it improper to urge him to a greater speed.

Previously to starting with the train, he should take care that the carriages are properly coupled, that the requisite number of break carriages are on, in the situations assigned

for them, and in proper working condition; that the luggage is properly and safely stowed, and that the requisite number of tarpaulins are securely fastened over it, so as to insure it being kept perfectly dry. He should ascertain that his parcels and documents of every kind are placed in the situations assigned for them; that the roof and signal lamps are attached in their proper places, and in efficient order; and that the carriages are in a proper state of cleanliness, reporting every deficiency, in these respects, to the foreman of the porters.

Should there be any inclined planes on the railway, where fixed engines are used in one direction, and gravity in the other, he must surrender the train, while on the inclined plane, to the charge of the bank-rider, communicating to him the number of carriages in the train, and the number of brakes in proper working order; and he must himself, as well as his under guard, act in entire obedience to the orders of the bank-rider, until the train leaves the inclined plane. The moment this takes place, he should again resume the sole direction of the train, taking the complete charge of the whole in the same degree as he did prior to arriving at the inclined plane.

He should not allow any passengers to stand up in the coaches whilst the train is in motion, nor in any other manner endanger themselves by improper exposure; and in case of accident or obstruction to the train, he should consider forwarding the passengers to be of the first importance, and when this proves impracticable, he should adopt the most speedy mode of communication in his power, to the next station or point where he can receive the necessary assistance. Should the accident unfortunately be of such a nature that any of the passengers have received injury, every thing else must of course give way to rendering them instant attention, and he should leave nothing untried to insure their safety. As a means to this end, every guard should be instructed in the use of the tourniquet, a supply

of which, with a few common bandages, should be carried with every train.

He should keep a journal, in which he should enter every circumstance of consequence, and an exact record of each journey, with the fullest particulars of the time of leaving and arriving at each station, and the cause of any detention; noting also, and reporting, any policemen, switchmen, or gate-keepers, who may be off their posts, or who may not shew the proper signals to the train; and any other instance of negligence, or improper conduct, which he may have observed during the journey. He must also obtain and report the name of any person travelling with a free pass, and he should be particular in noting any unusual or irregular motion in any of the carriages, taking care that at the next station it is examined into, besides which, he should forward his report of it to head-quarters. Before he begins to pack his luggage on the train, on first preparing to start, he should send round his under guard to examine and report to him that all the grease boxes are filled.

The upper and under guards should each be furnished with a hand lanthorn, shewing a white, green, and red light at pleasure. They should also have a lanthorn hung at one corner of the carriages on which they sit, capable of being turned round, and shewing, when the train is in motion, a white light forward, and a red light behind, if the train is not furnished with the self-acting lamps we have recommended. On approaching a stopping place, before the guards apply the brakes, they should both turn the red light forward, and when ready to start again, the upper guard should turn the white light forward, and the under guard should repeat it; the engine-man should then put on his steam. A lanthorn should be placed at each station so as to shew a red light to the trains which stop there, and a white light to those which pass. After using the brakes, the guards should ascertain that they have not taken fire, which they often do on the present construction.

Where inclined planes are used in a railway, where a fixed engine draws the carriages up the plane, and gravity brings them down, a bank-rider should be appointed to each of these inclines, who should have the entire control of the plane, and of every thing which passes on it, either up or down. He should make himself perfectly acquainted with the velocity acquired by trains of all descriptions, so as to be able in every case to apply the brakes in sufficient time to insure the stopping of the train at the proper moment. He should himself attach the rope to every train of carriages which are to be drawn up the plane, and suffer nothing to descend except conducted by him; and every man upon the train should be ordered implicitly to follow his directions.

He should carefully inspect the condition of every train, and never attempt to move it till he is perfectly satisfied of the safety of every part. He should frequently examine into the state of the ropes and sheaves, to ascertain that they are in proper condition, and that the sheave-axles are well greased. He should use all the vigilance in his power to prevent rubbish or obstructions of any kind from being put on the inclined plane; and he should give constant attention, not only to the brakes, but to the wheels, grease boxes, and other parts of the machinery of the carriages which come under his notice; reporting any negligence or imperfections which he may observe; at all times keeping himself provided with signal flags, and signal lamps properly trimmed.

When the rope is properly attached, which is best done by a selvagee strap, he should see that the shoe-drag is properly attached to the last carriage, in order to be able to stop the train with certainty should the rope break, and may then order the signal to be made for the fixed engine to start the train. This signal, if the fixed engine-house is in sight of the train, may be the white flag by day, and the white light by night; the red flag, or red light, having been exhibited

during the time the rope was being attached to the train. When the fixed engine-house is not in sight of the train, nor can be put in communication with the bank-rider by an additional signal, a whistle is the most commodious means of conveying the orders. For this purpose a pipe must be laid under ground from the place where the train is attached, to the engine-house; to the end of which, in the engine-house, the whistle should be fixed, whilst at the other end, the air is forcibly carried through the tube by lowering down an inverted hollow cylinder, open at the lower end, into a receiver of water, in the centre of which, above the water, is the pipe leading to the whistle. In curves on inclined planes worked by ropes, the top of the rope-roll and its horn, should lean to the convex side of the curve, but the whole roll should be bodily over towards the concave side, the name of the sides being taken from the outside edges of the rails. The hook which attaches the selvagee strap to the train, should be so constructed as to unhook of itself when the train has arrived at the top of the inclined plane, at which time the selvagee will come into a vertical position. Should the train require to be stopped during its ascent, the guard should shew a red flag to a look-out man placed near the fixed engine-house, and at the same time he should put on his brakes.

The whole of the clerks in the coaching and parcel departments, as well as the porters, guards, ticket collectors, and bank-riders, together with those employed in the carriage of horses, private carriages, and cattle, should be under the sole direction of the superintendent of the coaching department, or, as he is sometimes called, the coaching agent, who must bring all the different branches of the work into one focus, compiling from the various returns, reports, books, and papers, which should be transmitted to him daily and weekly, a summary of each day and week's transactions in the fullest possible manner; forwarding the necessary books, papers, and vouchers, as they are examined by him, to the

audit office; placing before the secretary all general results, tabulated, so as, at one view, to present the whole daily and weekly traffic and receipts of every kind; and he should be prepared at a moment's notice to exhibit every detail, from the collection of which the general tables have been compiled; and in the same manner transmitting to the store-keeper every transaction in his department, as received from the various stations, as soon as the proper examination has taken place.

In this, as well as in the goods' department, it must be seen that it will be impossible to proceed without the most perfect order and regularity. Each book and paper of every kind should have its place, and each day and week's work be thoroughly completed at the earliest possible opportunity. Files of the kind before described, should be kept for the papers belonging to each station, and for the guards' reports, foreman porter's reports, times of the arrival and departures from each station, luggage, ticket statements, and every other document connected with the coaching department in all its various branches, so that each series, of every class, can be at once got at and examined, as well as placed in security.

The parcels' office should form a branch of the coaching department, and in this office it will be found most convenient to send out and receive horses, cattle, and private carriages. There need only be a separate office for this at the principal terminus, or in towns where the traffic in parcels is unusually large; in the out-stations generally, it may be done with the other business of the coaching, in the passengers' booking office. Every parcel, before it is dispatched, should have a ticket pasted on it of one colour, for those which are to go the whole length of the line, and of another colour for those which do not, for the guidance of the guard. This ticket should state the sum to be paid for the carriage by the railway, which, in the most usual cases, may be printed on it; and also any money "paid on," that is to say, any

previous carriage paid by the railway company on receiving the parcel. It should contain a notice that no other charge is to be paid except that which is stated on the ticket, and also specify the extent of the company's liability. The head of the parcels' office should be responsible for all the money received, and should pay the preceding day's cash over to the cashier on the following morning, making good all deficiencies. This is the best plan both for the clerk and the company, as it not only insures the latter their full money, but it dispenses with a cash account, relieving the clerk of all trouble and anxiety on that head; it will also make him sufficiently vigilant in the collection of his money. Whenever, through a parcel being lost, the money for its carriage cannot be received, a certificate to that effect should be sent with a note of inquiry to the superintendent of the coaching, and to the cashier.

Tickets for horses, carriages, and cattle, should be issued in each case, similar in colour to those which have previously been described for passengers. There should be a duplicate of this left in the book, with a statement of the nature of the articles, their amount, and all other particulars. The tickets, when collected, should be compared with the books weekly, the clerk being accountable for every one which is found cut out of the book. The quickest way of detaching the tickets from the book is, by pressing down the edge of a piece of tin in the proper place, and by giving them a sharp pull, they will tear off close to the tin.

All books should be kept in duplicate, one set being in use for a week, whilst the set used the preceding week are being audited; the way-bills, receipts, and documents of every kind, should be forwarded to the coaching agent's office, at the principal terminus, for examination; and where summaries of the whole should be made, placing each class of articles under its proper head, and shewing the individual and aggregate totals. No "paid on" should be allowed without a receipt from the party to whom the money was

given. This receipt should be on different-coloured paper for each line of road, and it should state the amount paid, the description of the article, the address, the train it was forwarded by, the date, and the signature and address of the party receiving the money; and, as a general rule, the liability of the company should be printed at the bottom of every document which will meet the eye of the public.

The parcels' way-bill, coloured differently for each line, should shew the date, time of the train, (always being that on which it starts from either terminus,) the place from, and place to, the number of each class of articles as they come in, beginning each day with number one, the description and number of the articles, the name, address, the amount paid on, the amount paid for the carriage on the railway, and the total; each of these columns being added up, and the first and second added together at the bottom, and compared as a check with the amount of the third, with which, if the whole has been done correctly, it should agree, and if it does not, the error must be searched for till discovered. A daily summary of the horse and carriage book, should be pasted, at the end of the day's issue of tickets, in the ticket book, the rest of that page of tickets being partially destroyed. This summary should state the train, the number of pages of tickets issued, and their amount, on the left hand; and as a check, the number of the class of articles, the description, the rate of carriage, and the amount, on the right hand; both these, when summed up, should exactly agree, if the entries have been made correctly, otherwise the error must be searched for till discovered.

A weekly abstract of the horse and carriage-book differently coloured for each line, should be sent to the head parcels' office, giving the date, number, train, description, name, amount, and the place to which the articles have been conveyed; also a weekly abstract of the cattle-book, shewing the date, name, description, number, rate, place conveyed to, and amount of carriage. At the head parcels'-office,

there had better be two sets of books for each out-station, with two in each set, one for parcels inward, and the other for parcels outwards, using one set each alternate week, whilst the other set are being audited. The parcels inwards should contain the number in the delivery-book, train, station, number of the class of article in a consecutive series, beginning with number one each day, the name, address, paid on, amount paid for railway carriage, and the total amount. In the parcels' outwards-books, the first column of the inwards-book may be omitted, and the rest should be exactly the same.

The parcels' cash-book should show the daily receipts under the head of parcels, carriages, horses, cattle, and booking; the whole should be distinguished into "up" and "down," and these into "received" and "paid out," each day being summed up; and in the left-hand column, the total for the day should be again put, under which the cashier should set his initials when he receives the money. The horse and carriage, and the cattle-books, should be exactly similar to their abstracts which we have given above. The delivery-book should contain the date, the number of the parcels, description, name, address, paid on, carriage on railway paid, to pay, and a column for the signature of the person who receives the article. In all cases, where any thing whatever is sent forward, with a request that it may be left till called for, a receipt should be given for it, containing a description of the article, and its number, without the production of which the article should not be given up till the ownership of the person demanding it is fully proved.

In the parcels' office at the terminus, and in all the out-stations, tables of weights, and the charges for all distances, should be conspicuously hung up where every one can see them; also any regulations or bye-laws, and the liability of the company. Stamps should invariably be made use of instead of writing, and whenever it is practicable, the object being in all cases to dispatch the articles as ra-

pidly as possible, so as to continue booking to the latest possible time, leaving only the number of minutes necessary for making out the documents which are to go with the train ; the office should then be closed whilst these are making out, and at the out-stations the office should be closed invariably on the arrival of the train, and no person admitted into it except those in the company's employ, till the train has left.

We shall next describe the best mode, as at present adopted, of conducting the coaching business at the out-stations, and afterwards treat of what should be done at the principal terminus. The nature of the traffic will in all cases determine the number of persons employed, but in the out-stations all persons should be under the principal booking clerk, who should be the general superintendent over the whole of the company's interests ; and he must have assistance both in and out of the office according to the nature and quantity of the traffic.

The whole time and attention of every person engaged on a railway, ought of course to be given to the company's business, but the principal clerk at the out-stations need not be confined to the office the whole day, as there are many opportunities in which by collecting local information, and in various other ways, he may make himself very useful. He ought to be at the office one hour before the arrival and departure of every train, and not to leave it afterwards until the books are properly secured, or left in the charge of a competent person, as both them and all papers connected with the office are to be considered strictly confidential.

He should at all times shew uniform attention and civility to all the passengers, and to persons making inquiries, and should enforce the same line of conduct on all the other persons employed at the station, reporting every instance of the contrary to head-quarters. Proper persons should be appointed to give warning of the arrival of all trains, by

ringing an alarm-bell, so as to summon the porters and police to their attendance in time; and if the line is curved, additional persons should be stationed sufficiently in advance each way, so as to give full notice for everybody to be ready. When the bell rings, the office-door should be shut and fastened, nothing more being received or delivered till the train has gone, the whole attention of every person in the company's employ being directed to the train. With the exception of those times the office should be at all times accessible to every one.

The head booking-clerk being responsible for the whole arrangement of the business, and the management of the office, must state to the inspector of police, the foreman of the porters, and the foreman of the engine-house, all that he requires to be done in their several departments, but he should not interfere in the details of the out-door work, for which those persons ought to be responsible. He is to be accountable for all monies received for either passengers, carriages, parcels, or goods, which is to be duly handed over to him from those persons who are appointed to receive it at the several places where any thing is booked, and must make good all deficiencies, whether arising from bad money, local notes, or errors.

A general and special order-book should be kept at each out-station, accessible to everybody, in which all orders should be entered directly they are received. All information which can be collected from any quarter bearing on the interests of the company, should be transmitted to head-quarters as speedily as possible, and all persons should be invited to make any observations to the benefit of the company's service.

Neither the clerk, nor any other person, should be allowed to travel on the railway without a free pass from head quarters, except in cases of great emergency, the necessity for which should be judged of at the principal office; and strict directions ought in all cases to be given, that no parcels or pack-

ages of any kind should be transmitted along the railway without being duly entered and the carriage charged; strict regularity in the dispatch of business should be at all times insisted on as well as accuracy and neatness in books and accounts, and the clerk must at all times enforce cleanliness, both with respect to the persons of those employed as well as in the various buildings and offices.

The stores and stationery required should be drawn by a requisition-note from the store-keeper, sending at least one week if possible before they are wanted. An office memorandum-book should be kept, in which all occurrences, addresses, or other information, should be entered. The summary of fares should be completed on the departure of each train, the whole of the cash receipts should be transmitted to the head office every night by the last train, and the daily classification of fares for the preceding day every morning by the first train, together with the tickets collected, and the ticket statement. All books should be kept in duplicate, that is to say, one set of books should be used in one week, and another set in the next week, the first set being sent off on Monday morning to be audited, after which they should be returned to be used again in the succeeding week, during which the second set will be sent up for audit. The edges of the ticket-books should be coloured similarly to the tickets, that they may be distinguished without having to open them.

A weekly account-current should be sent up, and all errors should be explained and accounted for, and an excess and deficiency book kept to show every case, and how it arose. It should be emphatically impressed on each clerk, that a single instance of irregularity must of necessity interrupt the unity of arrangement throughout the whole line. All communications between the principal stations should be made on memorandum notes, with printed heading, on which the answers can be written across with red ink; and copies of any notes sent to any other out-station, should be sent

to head quarters. Stamps should be used whenever they can to save time, such as for the date and hour of the train, where from, where to, and in all other possible cases. For this purpose printers' ink is the best, laid on several folds of cloth, and kept in a round pewter box, the stamps being arranged on a stand, with their significations marked by their side; and amongst the rest a large flat circular one will be found useful to stamp over an error. It is called an obliterater.

Rules and regulations should be publicly placed up in the office, together with the fares, children under ten years of age being charged half, and infants in arms nothing. All things forwarded, of every description, should have a way-bill sent with them, and all things delivered should have the signature of the party receiving them in the delivery-book. When the cash is transmitted, a note should be sent, stating the quantity of gold, silver, notes, and copper, with the name of the guard who received it. These amounts must of course coincide with the classification of tickets sent up the next morning.

On the clerk's first arrival at the station, he should commence his business by making out his passengers' way-bill or docquet, which is to be given to the guard of the train, and must be made out in duplicate, one for up the line, and the other for down, of two different colours. These should state in printed forms, leaving as little to be written as possible, the station left, and that to which the passengers go, distinguishing the class of the carriage, adding up the totals, and shewing the time of the train leaving either terminus, by which time the train is distinguished. In the same way, the goods' and parcels' way-bills are made out, each parcel having a ticket pasted on it of one colour, if it is to go the whole length of the journey, and a different one if it is to stop at another station, for the guidance of the guard. The amount of carriage for each parcel is stated on this ticket, with a notification how far the company are liable for risk.

A summary of each departure train should be made out directly it has gone from the station, shewing the number of each sort of tickets, the amount paid, the number of passengers, and their fare, and both sides being summed up, should of course agree in amount. A statement of excess fares must also be made, stating date, time of train, whether up or down, the class, from where, to where, the amount paid, and the reason why the excess arose, such as a passenger changing the class of his carriage during the journey, or changing the place of his destination.

The classification of daily totals, should be in two different-coloured sheets, one for up, and the other for down, except at the termini ; they should shew the station and date, and have a double column for each station, one for the first-class passengers, and one for the second; a column for the time of the train on the left-hand, and a column for the cash on the right; the whole passengers being totalled at each station, and also brought into one general total, and the money also totalled, to which is to be added the money received for goods, parcels, horses, carriages, cattle, and booking ; all of which should be transmitted through the principal booking-clerk.

The tickets, which should be of different colours for up and down, and for each class of carriage, should be collected by the guards from the passengers at the last station before the termination of their journey, the upper guard taking the first class, and the under the second class, a ticket collector accompanying the upper guard to receive the tickets and money where excess fares occur, and a trusty porter doing the same with the under guard. The tickets, when collected, should be given to the head booking-clerk for assortment, and by him sent to the principal office the following morning, except where passengers get down at any out-station, in which case their tickets are to be collected by a man stationed for that purpose at a wicket, where only one person can get through at a time; and the collector must

see that each ticket is issued to take the bearer to the station where he has got down. When passengers are going from this last station to the terminus, they should all be put in the carriages previous to the guard going round to collect the tickets, that he may get theirs also.

A statement of tickets collected at the station wicket, must be sent in on the following morning, stating the station, the time of the train, the class of ticket, with double columns for each station from which passengers could come, one for the number of tickets collected, the other for the number issued. This latter column should be filled in at the audit-office. On this return should be noted all passes, and by whom. Those authorised to give passes should keep a pass-book, on the margin of which, in each case, must be stated to whom the pass was given, for where, and on what business; this may be examined weekly, by having two of them, and using them alternately. If it is thought proper, cards may be used instead of tickets, where passengers are only going from one intermediate station to another, in which case, they should be issued from the audit-office with a private mark, and a card summary should be sent in daily in the same manner as is done with the tickets; the cards also must be collected and transmitted daily in all respects the same as the tickets.

The weekly account-current is a compendium of the daily classifications thrown into the form of debtor and creditor, shewing the whole money received, and the total number of passengers of each class, the amount received for parcels, goods, and all other sources, with the name of each station for which the tickets are issued. The neatest way of keeping the ticket-books is never to enter in the summary of tickets issued, any fraction of a page, but merely the number of pages at each price, cutting off any odd tickets, and pasting them on the back of the margin. There should also be files for each station hanging up in the office similar to those we have described in the engineer department.

Daily summaries of the horse-book, carriage-book, goods' accounts, and all other transactions, by pages, as before described, must be sent as way-bills with each train; both sides being balanced, and a duplicate pasted, at the end of the day, on the margin of the last page of tickets in the ticket-book, weekly, debtor and creditor accounts being transmitted in the accounts-current.

At the termini, the general method of conducting the coaching business is the same, except that at the principal one there should be a cashier, who should have charge of the booking-office, and the control of all the persons who are employed in it, and also the sole custody of all money received, which is to be transmitted to him by the several booking-clerks at the principal station, as soon as possible after every train; and by the booking-clerks at all the other stations every night by the last train; the total amount received for the day being by him paid into the appointed bank on the following morning, the whole of the receipts passing through his hands only, and he alone being responsible for the accuracy of the accounts, and the punctual dispatch of the business of the office. He should also prepare the daily statement of the passengers and fares, the weekly account-current, making likewise the calculation and monthly payment of the government duty at the stamp-office.

In order to ascertain with quickness and precision whether the passengers and the tickets, or other documents, are passing to or from the principal terminus, the distinguishing marks, UP and DOWN, should be conspicuously printed on all the respective documents, according to the road they are taking, as well as having different-coloured paper for all those which are going different ways; for instance, in the tickets, white and pink for the first and second class going one way, and yellow and blue for the same classes going the contrary way; and, if there are more than two classes, more colours must be employed.

On paying their fares, each person receives one of these

tickets, on which should be printed the date of the month, and year, the hour of departure, the name of the place from whence the person is going, the name of the place he is going to, and the sum paid for each ticket. These being torn from a book, each ticket leaves a marginal duplicate of the number and amount paid, which amount being added up, is carried into the summary or document, which shews the traffic for the train, from that particular book; to ensure the correctness of which, the number of passengers, and the amounts paid by each, should be calculated two ways on the same paper; one by taking the amounts of each page, and the other by taking the number of passengers, and the price of each; and, if these are correctly calculated, of course both ways will shew the same amount. From these are afterwards made out the classification of the daily totals, which shew the number of each class to every station, for each train, every day; also the amount received for each train, and for the whole day. From this is compiled the account-current, shewing the debtor and creditor account of the cashier with the company. In this, the number and amount of the fares should be again calclulated in a different manner, shewing the number of each class to each place, and the amount received for them on each day, the total amount, and the number of each class for the day; also the daily amount received from all other sources of traffic, always distinguishing the several kinds.

In all papers used in a railway office, every part that is practicable should be printed, and writing avoided on every one of the public documents as much as possible. To this end stamps should be made use of whenever they can; by which means much time will be saved, and the business conducted in a more satisfactory manner. If it is thought proper, as is the case on some railways, separate ticket-books to each out-station may be used at the termini, but it will give much additional trouble, as will also the skeleton

plans of coaches, in which the names of the passengers are written in their seats. We should recommend neither.

All the returns, of every necessary kind, from the out-stations, must be abstracted, summed up, and duly entered in books, to be provided at the general office at the principal station; such as the daily returns of passengers and fares, the weekly accounts-current, the summaries of tickets collected, &c., so as to be able at one view to state the daily, weekly, and quarterly receipts, in the most clear and distinct form. The above is the most approved mode of conducting the business in the coaching department. All the minutiæ of these departments should be rigidly examined in the audit office; after which, only the results need be transmitted to the general office; but all the details should of course be sent to the coaching agent.

In the store department, the secretary should have counterparts of all contracts for stores, and duplicate contract-books, also duplicates of all invoices for stores supplied to the store-keeper. These should be filled into blank forms, furnished for that purpose, to the tradesmen or contractors, of which three sizes should be made, viz. a half sheet, a quarter sheet, and one of a length midway between these, so that they will always fold into one uniform shape for putting away. By means of these duplicates, the secretary, or his examining clerk, can always check the receipt of stores before he allows them to be paid for.

The store-keeper should have the entire custody and supervision of all materials, utensils, tools, and implements of every kind, which may be used in any department whatever; also of all stationery, books, printed forms, and other printed documents connected with working the line; and all coke, oil, waste, and other articles required in the locomotive department. He should superintend the distribution of all these various things, and must keep very accurate and correct accounts, so as to be able, at any required

moment, to shew the whole he has received and delivered, and likewise what remains on hand, of each article which he has had in charge; and the heads of those departments who are in the receipt of stores, should keep in all cases similar accounts, copies of which should be periodically transmitted to the store-keeper.

When any article is required for the use of a department, a requisition-note or indent should be addressed to the store-keeper by the head of the department; this forms the store-keeper's voucher for the demand. If in store the article should be immediately supplied, and a receipt-note, fully descriptive of it, and containing the date and place of delivery, should be signed by the persons who receive it; this forms the store-keeper's voucher for the issue.

If the article should have to be purchased (which, if proper warning is given, ought never to happen when it is wanted for use) the store-keeper should then insert the description, quantity, &c. in the contract-book. This book should contain columns for the date, name of the contractor, nature of the commodity, and the quantity required, the price, place of delivery, and the department the article is intended for; accompanied by a statement of the circumstances attending the demand, and the time when the article is required. This book should be laid before the directors at their next meeting; and, if they sanction the supply of the article, the store-keeper should then send his order-note to the person who is to furnish it. These order-notes should be bound up in a book, and the particulars of each entered on the margin before the note is cut out; each order-note should contain the time and place for the delivery of the article, and on the margin should be entered the page in the contract-book, and that in the receipt-book. No article should be paid for, unless the order-note, signed by the store-keeper, is produced by the tradesman; and a notice to this effect should be printed on the note. A delivery note and invoice should always accompany each article.

The contract-book should also contain the date and number of the minute authorising the supply of the article ; together with any conditions which are attached, and the recognition of those conditions, by the signature of the secretary, and, in another column, by that of the person who is to supply the commodity ; also the date when received, the name of the person who received it, the date of the payment, and a reference to the account.

A record of the orders and receipts should be kept in a book, shewing the date and number of the order, the tradesman's name and address, the nature and quantity of the commodity, the place, time, and quantity delivered, and a proper reference to the goods-received book. In the same manner a record-book should be kept of all requisitions for the supply of stores from the different departments, distinguishing the number of the requisition for each department separately, the nature and quantity of the article required, the time when it was supplied, the place of delivery, the quantity delivered, and the proper reference to the goods-delivered book.

The goods-received book should shew the date of the receipt of each article, and from whom, the nature and quantity, the place of delivery, the number in the order-book and on the delivery-note, and the page in the journal. The goods-delivery book should shew the date, the number of the requisition-note, each department being separate, the nature and quantity of the article, the place where it was delivered, the time when it was required, the time when it was delivered, the number of the receipt-note, and the page in the journal. These two books should be posted weekly into the journal, if one is kept, strictly observing the principles of double entry. It is not, however, absolutely necessary to have a journal, as the goods-received and goods-delivery books will answer the same purpose.

The store-keeper's ledger should be in three distinct parts, which should, at all times, shew the exact quantity of every

article received, issued, or remaining in store. The stock-ledger should shew, on the debtor side, from whom the article was received, the date, the page in the journal, and the quantity and particulars of the commodity; and on the creditor side, the date when delivered, to whom, the quantity and particulars, and the page in the journal. The tradesman's ledger should shew, on the debtor side, the date when the article was paid for, the number of the pay-bill and voucher, the quantity, weight, and other particulars, the rate, or contract price, and the amount; and on the creditor side, the date when delivered, the page in the journal, the quantity, weight, and particulars, and the contract price. The department ledger should exhibit the supply to each department, classified under separate heads.

The whole should be kept so clear and distinct, that a precise view of the state of the accounts can at any time be had. The ledger should be balanced and stock taken every three months, at which times a detailed account should be prepared for the directors, together with a statement from each department, exhibiting the application of the articles supplied from the stores, and a recapitulation of those remaining unused, which it is the duty of the store-keeper to see actually produced.

Whenever requisitions are addressed to him, he should supply them as promptly as possible; and, while he guards against any inconvenience which must necessarily arise from his having an insufficient supply of those articles which are in general use or consumption, he must, at the same time, be very careful that the stock in hand is not larger than what is absolutely required. He should cause strict attention to be paid to the quality and condition of the articles supplied, rejecting in every case all those which may be defective; and the same care should be scrupulously observed by the head of each department.

The condition of the articles in store should be vigilantly observed; and whenever any quantity may have accumu-

lated which are unserviceable, or which may be advantageously converted into other uses, the directors should be immediately informed of it, and their orders taken on the subject. All payments ought to be made in cash or at cash prices ; and the store-keeper, after he has examined the invoices and the goods as to quantity and quality, and placed on them the necessary references to his books, should remit duplicates of them, signed by the contractor and himself, to the secretary for payment.

In making out his balance sheets, they should shew the expenditure of stores at each station, and in each department, the one being a check on the other. Each should have an alphabetical enumeration of the articles down the left-hand column ; then in the station sheet, there should be a column to contain the issues to each station ; these, when summed up, and taken from the total receipts, will shew the balance on hand. In the department sheet, after the alphabetical enumeration, should come the balance of each from the previous quarter ; these together form the total debtor side ; the distribution to the various departments form the creditor side, and their difference the balance on hand, the correctness of the whole being insured by taking stock, and an examination by the audit office.

The store-house should be so situated, that there is easy access to it by carts on the one side, and from it by railway waggons on the other, stages or platforms being provided in each case, equal in height to the bottoms of the carts and waggons, so that the articles coming or going may be rolled on and off on a level. There should also be plenty of convenient room for storing timber to season, and the whole should be enclosed. It should be divided in such a manner, that every article in store has its particular place, the heavy articles being separated from those which are portable, and those for each department being kept as much as possible together ; oils, paint, grease, and all other inflammable matters, being thoroughly secured from fire, and all

metallic articles protected as much as possible from damp. A small smithy, with a few work-benches, will be useful adjuncts, for the purpose of repairing tools, and converting worn out articles into others. No one law should be more rigidly observed, than that the remains of all articles worn out from every station, and in every department, should be invariably returned into store; the parties who received them being held strictly responsible on this point, and in default of their doing so, they should be charged with, at least, half their cost price.

We have next to describe the mode of working the goods' department; and if there is much traffic expected in this branch of the business, it will be more essential to have a thoroughly correct and systematic mode of carrying it on through its minutest details, than is required even in the passenger department, inasmuch as the passengers can take care of themselves in some measure, whereas the whole responsibility of the goods must depend on their transit being conducted on right principles. It is not yet by any means certain that the carriage of heavy goods is advantageous to a railway in a pecuniary point of view; but the questions which have arisen on this point, could only have been admitted to discussion in the extent they have, through waggons with insufficient springs being made use of. It should always be remembered, that on a railway the best springs should be employed for all the vehicles which run on it, whereas they are generally confined to the passenger carriages, and sometimes only to the better sort of these; their intention is, as much to prevent damage to the road by reaction, as to conduce to the comfort and convenience of the travellers in the trains.

The main thing to be looked to in the goods' station is, plenty of room and plenty of shelter, hence, as large a space of ground should be covered with shedding as can be procured. The quantity of warehouse room will be in a great measure regulated by the traffic, but it will in almost every

case be less than what is required in the various establishments, either by waggon or canal. Platforms should be built amply sufficient for all the anticipated trade, of such a height, and in such situations, that goods which are brought into the station by carts or waggons can back against them, and roll or cut their goods out on to them, while, in each case, a line of rails is laid on the other side of the platform, on which the railway waggons come up to receive the goods after they are weighed, and the proper account has been taken of them on the platform.

The railway waggons for general purposes are best made with a floor, and sides rising only about two inches, having depth downwards instead of above the floor, with barred sides taking off and on, so that the side next the platform being unshipped, the goods are rolled or cut into the waggon according to their form. Where the trade consists in any quantity of peculiar articles, waggons to suit them must be made, and any expense laid out for this purpose will be amply repaid by the facilities which will be afforded in rapidly passing along the goods, and making up the trains, by many of the sides taking off and on; long articles, such as timber, may be laid on two or more waggons to divide the weight, pivot stages being provided to suit the curves.

Under the sides of each waggon, in a convenient place next the framing, should be fixed a cylinder about three inches in diameter, and ten inches long, having a horizontal slit on its outside for nearly the whole length, and about three-quarters or an inch broad; inside this should revolve another cylinder capable of being turned round by a key at one end. On this inner cylinder should be painted the names of the various stations at which the goods are to be left; and on the waggon being loaded for any particular station, the inner cylinder should be turned round by the key till the name of the station to which it is going appears through the slit in the outer cylinder. Goods for two stations should never be put on the same waggon, and waggons

should be coupled in the train in the order in which they will be required to be left at the several stations. The cylinders should be fixed on that side of the waggons which will be adjacent to the goods' station on their arrival, whereever this is practicable.

Dispatch bags should be provided for the purpose of carrying the invoices, advice notes, and other documents, from one station to another, having slips of brass with the names of the stations engraved on them (one for each). No more than the papers for one station should be put in each bag. The slip of brass should fix on the catch of the lock, and be fastened down by the process of locking the bag; when it arrives at its destination the papers are taken out by the clerk, and the bag is then available for any other journey, by merely changing the brass label; the labels not in use being all fixed to a small chain, and put inside the bag.

The number of cranes, weighing machines, and their form, must be determined by the nature of the traffic; but if this is considerable, there can be no error in having an ample supply, as well as of all the various implements for hooking, slinging, moving, &c. adapted to the sort of goods the trade will principally consist in; together with convenient trucks for transporting articles of every kind, and a full stock of cordage, tarpaulins, &c. The line of rails from the platforms should run into the warehouses, so that the waggons which have brought in goods requiring to be retained for any length of time may be rolled off at once, after an account of the respective articles they contain is taken at the platform, and deposited in a place of security.

A guard and brakesman should go with each goods' train, the guard having the entire charge of the train and all it contains, the brakesman being under his orders; steady seamen are found to be the best men for this latter duty, from their being so much accustomed to the peculiar lashings, &c. The guard should have the charge of the various dispatch bags for the different stations, for the safe custody of which

he should be allowed a lock-up box, placed in a convenient manner on the waggon in which he rides. He should deliver his bags to no other person except the clerk of the station, or some one specifically appointed to receive them; and in the same manner he will receive from the proper person any dispatch bags which are to be carried on to any other station.

In loading the waggons care should be taken that the heavy and light articles for each station are so apportioned in all the waggons, that no one is overloaded nor unnecessarily top-heavy, and that no damage can arise to one kind of articles, by their being stowed near others of a nature injurious to them. From sea-port towns, for instance, fish will form a large article of traffic, most probably, in summer, packed in ice, if the journey is a long one; and in all cases separate waggons should be provided for this, having holes in the bottom for the drainage to run out; these waggons should be well washed at the termination of every journey, and sprinkled with chloride of lime, as well as the stages, where any unpleasant smell is perceived. The empty waggons should at all times be kept under cover, and thoroughly swept and cleaned after each journey.

There will hardly ever arise any necessity for lock-up waggons for any purpose. If the guard is commonly attentive, and never leaves the train at any station without the brakesman remaining with it, there will be so small a chance of any frauds being committed without their being seen, that it must be under very peculiar circumstances any preventive measures of that kind need be taken. With wine and spirits, the most satisfactory way for all parties, will be, to take the weight, the dip, the number of gallons, and the proof, both before it goes away, and after its arrival: should the parties to whom it belongs object to samples being thus taken, it should be invoiced as "contents and quality unknown," and the railway company should throw off all responsibility. The samples, if claimed by the own-

ers, should likewise, by being given up, exonerate the company from any farther claim; and if they are not demanded, they may, after a year's lapse of time, be given to a charitable institution. This is the mode practised by some of the best regulated railway companies.

Goods may be brought to the railway station in several ways; first, by canal or by carriers' waggons in large quantities, of all kinds, and belonging to different owners. In this case, on their being received, the carrier or boatman, as the case may be, should be paid his demands at once on the spot, and he should be furnished with a statement of every article he has delivered, containing the date, species of goods, to whom consigned, at what place, the mark, weight, rate of freight forward, paid on, and total amount; this should be signed by the receiving clerk, and a counterpart sent to the goods' booking-office, from which the invoice is afterwards made out.

Secondly, by the owner's own waggons or carts; the person who receives them then fills up a carriage-note, containing the date, from whom the goods come, to whom they are to go, by what time they are wished to arrive at the destination, and the description and weight of the articles. This note is forwarded to the goods' office as a datum for the invoice. Sometimes articles are requested to be kept at the end of their journey till called for; in that case a receipt-note should be given to the owners, being a counterpart of the carriage-note, and in the invoice these goods should be noted as "per receipt;" they should then not be given up, except the person who applies for them produces his receipt.

Thirdly, they may be collected in the adjacent towns by the company's carts or waggons, and brought to the station by them. In this case the carter enters them into a rough book, from which the carriage-notes are made out for each on their arrival at the station, and they are weighed, and their notes forwarded to the office as before. In the same

way they may be sent from the station for delivery, either in the company's carts or waggons, which some companies do free of expense, others making a charge for this carriage; or the owners may send for them; and, lastly, properly authorised public carriers may be allowed to undertake the delivery. In each case a freight or delivery-note should be sent to be left with the goods; containing the date, name of the party receiving them, name of the party from whom they came, the number of packages, the species of goods, the marks, weight, rate of carriage, paid on, cartage, if any, and the total amount; and on this and every other document issued to the public, the liability of the company as carriers should be clearly stated. When the parties themselves fetch them away, they of course pay the freight, unless accounts are opened with them, and when carried forward, then they should pay all the charge before taking them away, and sign a receipt-note for the whole of the articles.

When the railway company deliver them by their own carts or waggons, the carter should take with him a town-delivery book, in which should be previously entered in the goods' office the number of the invoice, address, species of goods, folio in the office invoice book, weight, rate of carriage, paid on, and total amount. He should have directions not to deliver the goods without receiving money, unless in cases where accounts are kept with well-known parties, and he is of course accountable for the charges entered in his delivery book, the last column of which should be for the signature of the parties receiving the articles in question.

Recurring now to where the goods are received on the station, in whatever way they may have been brought, and the carriage notes sent to the goods' office, the directions come from thence as to the loading for the next train, the number of stations for which waggons will have to be provided, and their probable number. The invoices are next made out, a separate one for every waggon, separate waggons being always loaded for each station. The in-

voices should be printed of different lengths to suit the quantity of articles going by different waggons; each should be numbered, and contain the number of the waggon, with the date, hour of the train, a blank for the hour of arrival, the place from, and the place to, as a heading; then, in columns, the consigner, consignee, address, number of packages, species of goods, marks, weight; in double columns, one for each station, the one they are sent from, and the one they are sent to; rate of carriage, paid on, total amount to be accounted for from the station the goods went from, total amount to be accounted for from the station the goods were sent to, cartage, sum porters are to collect on delivery, amount of carriage posted to parties with whom accounts are opened, the folio in " goods-forwarded" book, and the amount of any over or under charge.

As the accounts of the goods are received in the goods' office, they should be entered in the forwarding book. This should contain, on the left hand page, the date when the articles were invoiced, and, in columns, the date when the goods were received, the number of the carriage note, (their numbers may run on consecutively for a month,) the consigner, the consignee, and the species of goods; and on the right hand column the place the goods are sent to, the number of the waggon, the number or name of the engine, and the hour of the train; and, in columns, the weight, rate of carriage, paid on; paid, (when the carriage is paid); to pay, (at their destination); porters, (money to be received for carriage by delivery porters;) posted, (money placed to the debit of parties with whom accounts are kept); overcharge, undercharge, folio in goods' received book, and the number of the invoice. This book should be summed up as to weight and money for each waggon.

Where accounts are kept for carriage with any persons, the sums in the above column of " posted" should be carried to the separate *Dr.* and *Cr.* accounts of each party in an outstanding book kept for that purpose, which accounts

should be settled every month, and a balance struck. From the forwarding book the account of the goods should be transferred into the goods-received book, where one page will contain all the items necessary; namely, date, number of invoice, weight, paid on, paid, to pay, amount to porters, amount posted, undercharged, overcharged, and a column for remarks. This book should be made up each day for the business which was done on the preceding.

In this, as in every other department, every document, as far as possible, should be printed, and stamps should also be made use of, so that as little as possible is left to be done by writing. This not only ensures rapidity, which is of such vital importance, but also conduces to economy in no inconsiderable degree, one clerk being able to do as much work in a short time as two or three, if writing had to be gone through; and although the same high degree of celerity in transmitting goods is not so indispensable as is the case in the passenger department, yet where much business has to be done, it will be found exceedingly advantageous to possess every facility which the above arrangements will afford.

With this view, memorandum notes for all the most usual inquiries should be strung and ranged on hooks round the office, so as to be constantly at hand, and merely requiring to be filled in with the date, and the subject inquired after. A few of these we may give as examples; for instance, one headed "inquiry," in which, after the date, appears as follows: 'we are applied to for eight *chests marked* $\bar{\text{A}}$. said to be sent by *J. Jones to H. Williams,* from *Stafford* to *Liverpool;* inquire for the same." Here the words in italics only should be written.

Another form required would be for goods invoiced but not received, and for goods received but not invoiced; another for goods sent away, but which have not arrived at their destination. Another for wrong weights and wrong charges on the invoices received. Another to inquire respecting the state of any articles when received, on which

claims are made for damages. To those and many other similar inquiries, the replies should be forwarded by filling up blank "answer notes;" and where the business is considerable, these memoranda will be continually travelling backwards and forwards, saving all the trouble and formality of letters.

We have before adverted to the mode of taking samples of wine and spirits. These should be always entered in a book kept for that purpose, containing, in columns, the date, number of sample, number of invoice, name, description of the cask or package, nature of its contents, the dip, number of gallons, weight, proof, and, lastly, how the sample was ultimately disposed of, with the date. By constantly keeping up this system, not only will any frauds be prevented by the servants of the company, but all improper claims for leakages or deterioration, will be prevented.

The wages of the clerks, weighers, stablemen, porters, carters, &c. should be made out by pay-bill, as we have before shewn for other departments, and the stores drawn, and their accounts kept, in the same way which we have previously explained, every thing being clearly and accurately balanced and entered in such a way as at all times to shew the exact state of each account at the shortest possible warning, affording at the same time a full and complete check upon every money transaction.

The following general instructions for conducting the business, will explain all the leading features of the details. On the receiving side, care should be taken that the time of arrival of each waggon or train, should be noted on the invoice in its proper place, and that the charges in the invoices are correct in rate and amount; if not, the necessary alterations must be stated, either over or undercharge, as the case may be, but the original figures should not be erased or changed. A memorandum of these errors should be sent to the office from which the invoice came, and also to the head office.

The several charges should then be carried out into the column of porters, or posted, as described, in the goods-received book; and every article should be entered either in the delivery or warehouse-book, as the case may require, with the proper references in the column for that purpose, making a distinction in the delivery-book where the carriage money is not to be collected on delivery, if accounts current are kept with any parties. When these things are done, one side of the invoice will be cleared.

Every thing should be counted and weighed as it is taken out of the waggon, and ticked off on the invoice, so that both number and weight may be certified in case of dispute. When each waggon is clear, the clerk should sign the invoice, thereby certifying that the goods correspond with the entries; and, if otherwise, the variation should be marked, together with the number of any memorandum which it may be necessary to send thereupon. Delivery notes should be made out and sent with each parcel of goods, the number of the invoice being marked on each package, after which the invoices, in a consecutive series, should be posted into a skeleton book. As the money is brought in it should be entered from the delivery-book into the porter's settling-book, the folio of which should be marked, both in the delivery-book and in the last column of the invoice. This clears the other side of the invoice.

Where any goods are of a nature to render them liable to pillage, great care should be taken to weigh them very exactly, noticing, opposite to each article on the invoice, the least variation; spirits, wines, &c. being sampled, as before described. The porters should deliver no goods without payment, unless by particular authority from the office, and this authority should only be granted in the case of recognised parties with whom accounts are opened.

When the different columns are added up, and it is found that the sums posted and those in the porter's column agree with the total to pay, allowing for the over and under-

charges, if any, the invoice is then ready for posting to the account of goods received. The delivery-book should be examined daily, in order to see that each article is signed for by the parties receiving it: and if, through a dispute or any other cause, the carriage of any article is not paid for in due course, an entry of it should be made in the outstanding book, and a reference made to this instead of to the porter's settling-book. When any goods are brought back without any chance of immediate delivery, they must be entered in the warehouse-book, and the delivery-book should be referred to; also when goods are refused; in each case a memorandum of advice should be sent immediately, both to the office from which they came, and to the head office. When the articles are perishable, as live stock, the memorandum paper should be rendered conspicuous, either by a difference of colour or shape. Goods delivered to order should have the number of the order entered on the invoice. Carriers who receive goods should, in all cases, sign the delivery-book. All charges for warehouse room should be brought forward and received on the goods being taken away. All articles liable either to waste or pillage, should be reweighed on delivery from the warehouse.

On the forwarding side nothing should be received without a carriage-note, and if this is not sent with the goods, one should be made out and signed by the parties from whom the articles come. These carriage-notes form the basis of the invoices, and, as the goods are put on the waggons, a progressive number should be put on each carriage-note, and also the number of the waggon in which the goods to which it relates are sent; the notes should then be filed, and, as the load of each waggon is completed, the carriage notes for that waggon should be pinned together, and transmitted to the office for entry in the forwarding-book, and for the invoice to be made out. If it should be necessary to put the articles on one carriage-note in differ-

ent waggons, a separate carriage-note should be made out for those which are detached, with a reference on it to the original.

Each waggon load should be progressively numbered in the forwarding-book and kept separated; the columns being summed up, and every invoice an exact copy of the entries in the book. Every article should be most carefully weighed and ticketed as received, so that it can be certified if necessary; the consigners' marks should be entered, and all appearance of damage or irregularity in the condition of the packages or goods, should be referred to, both on the receipt and carriage-notes, particularly when received from other carriers. No receipts should be given except on the company's printed forms, especially for goods liable to damage or breakage; and when check receipts are given for goods going to order, this should be noted on the invoice. When each invoice is copied, it should invariably be called over with the forwarding-book.

The paid on's should be always entered at once in the proper book; and it is usual to charge 5 per cent. commission on these. Nothing should be paid on empties, nor on returned goods, without the consent of the consignee, to whom it is wished to return them; and, in all cases, nothing but the actual carriage should be paid, the total sum not being allowed to exceed half the apparent value of the goods.

A strict night-watch should be kept in the goods'-station, the various men noting on a slate every unusual occurrence, and the time it takes place. All goods liable to waste or damage, should be placed in the care of the most trusty men, their state and condition being inspected by the clerk and watchman, when the latter comes on his beat, by the two watchmen conjointly when there are reliefs, and by the clerk and watchman in the morning, before the latter goes off his beat. It will generally be found most advantageous to work the goods' trains in the day only; but when night-

trains must be run, watchmen may, to a certain extent, be reduced.

Where the business is very extensive, it will conduce to much regularity, and save a considerable portion of time, if the invoices are printed on different-coloured paper, so as at one view to distinguish those which are going each way, and those which go the whole length of the line, from those which stop at the intermediate stations, in the mode which we have recommended for the tickets, &c., in the coaching department; particularly where the intermediate stations are not both large and commodious, so that the receiving and forwarding department are perfectly separate in all their branches.

Tables of rates should be kept for all weights and distances, and for every species of goods likely to come along the line. These should be arranged alphabeticallly, and also according to price. When articles arrive for carriage which fall under no class, the fairest way of charging their freight will be to ascertain what sum each waggon should pay to afford a proper remuneration to the company. For instance, on a line 100 miles long, a goods' waggon ought to pay about L.4, and any goods not in the scale of charges should be priced according to the room they take up; for instance, if they employ one-fourth of a waggon, and are going the whole distance, their frieght should be L.1; and so on in proportion, according to room and distance.

We have next to describe the audit department, which is one of considerable importance, inasmuch as it ought to be a complete and perfect check on all the details of every other branch of expenditure, through every department in the management of a railway; rigidly examining, calculating, and checking every item throughout the whole of the accounts, and certifying the accuracy of the whole, or referring them back to receive corrections or explanations whenever it is necessary.

The local requisites for an audit-office, are seclusion,

ample space and good mechanical conveniences for arranging documents, however voluminous, and for storing up vouchers, which should, in all cases, be kept in this office after the various accounts are passed ; the signature of the head of the audit department to each document or book which he passes as correct, forming an understood receipt to the head of the department to which the book or document appertains, that the vouchers have been found accurate, and are deposited in the proper place.

It must be invariably remembered, that an audit-office, however perfect in its principles, its arrangements, and in all its various details, yet, if it is not raised to its proper position in the establishment; if its regulations have not the sanction of the highest authorities ; if every infraction of them, in whatever quarter, is not followed by the infliction of due punishment ; and if the independence of those attached to it is not secured by their being fully protected against any little annoyances to which their somewhat invidious duties may be likely to subject them, an audit-office will not only be an expensive incumbrance, but a dangerous deception, seeming to guard interests which it has not the power to protect, and opening a door to a laxity in the various departments in preparing their accounts, instead of exciting all to superior vigilance.

The whole management of the system of audit should be so modified, as to render it as little cumbrous and expensive as possible ; and great care should be taken that it is suited to the nature of the traffic and its extent. Incompetence and negligence on the part of the company's servants, should be perfectly guarded against ; and although, perhaps, it is a moral impossibility to prevent a fraudulent combination being for a time successful, yet it so greatly multiplies the chances of detection, as to afford to a railway company's interests, as much protection as can be obtained, without obliging every clerk who handles money to provide ample securities.

In organizing this department, it may be advantageously divided into three branches, viz. coaching, carrying, and sundries. The latter branch should include the audit of the stores, miscellaneous accounts, finance department, transfers, interest and dividend warrants, and all the payments for salaries and wages. This will include every branch of expenditure and receipt. For instance, the engineering department, as far as the maintenance of the way is concerned, draws all tools and materials from the stores, and all wages by pay-bill; hence, when these are checked, the engineering department is checked also. In like manner, the construction department is included in the stores and wages, and is audited when they are audited. In a similar way, the locomotive branch of the engineering department is examined.

In the coaching branch of the audit, which includes parcels, &c., the system to be organized for checking this portion of the traffic, should embrace the following objects: That the proper fare is paid by every passenger, and the proper charge for all cattle, and for each parcel, horse, private carriage, &c. That passengers going beyond their original destination, pay the proper additional fares; and that every sum of money received is rigidly traced through every stage, from the moment of its reception by any of the company's servants, till the instant in which it is deposited in the bank.

The ticket-books and cards (if used) should all be originally sent to every station from the audit-office, carefully numbered and registered; and when the week's books are transmitted to the audit-office for examination, every ticket which is not accounted for in the summary, or is not exhibited or pasted in the book, should be immediately placed to the debit of the station clerk.

The use of cards, as well as tickets, being to distinguish the out-station traffic from that between the termini, a number of cards proportional to the general quantity of the

traffic, should be sent weekly to each station, numbered and stamped with a private mark, as well as with the names of the stations between which they are intended to pass. A register of them is kept in the card-issue book, and the several station clerks being debited with the quantity sent to them, and credited with their daily issues taken from their summary at the close of the week, they return those remaining on hand to the audit-office ; and if these do not correspond with the quantity standing against them in the card-issue book, the clerks are made accountable for the difference.

The classification of fares, or the document exhibiting the daily result of the issues of cards or tickets at each station, should be compared weekly with the ticket-book summaries, and daily with the card summaries, the accuracy of the calculations having been previously tested. The weekly account current, which is a compendium of the daily classifications, is also checked. This completes the examination of the cash documents connected with passengers.

The collected tickets from all the stations having performed their office, are sent to be audited by the first train, on the day succeeding that on which they have been collected, accompanied with a detailed statement. They are counted in the audit-office. The excess fares are examined scrupulously, and compared with the guards' journals. The lost ticket-book is checked in the same way, and the banker's book compared with the general account current. For the purpose of sorting, classifying, counting, numbering, and stamping the cards and tickets, it will be best to employ young lads, under the superintendence of the examining clerk.

The parcels' books, inwards and outwards, are examined in a similar manner ; and if any difference is found to exist, the original way-bills are referred to, and the error traced to its source, when the responsible party is made accountable for the difference. The horse and carriage, and cattle accounts, go through a similar process ; and when

the totals are compared with the entries in the general account current, where every thing is introduced into one weekly total, the examination is complete.

A schedule of errors should be prepared weekly for each station, in which every omission or negligence should be noted, of whatever description, which may have taken place during the previous week. An explanation is then demanded for every irregularity; the proper persons are made accountable for all deficient cash; and mere errors of figures may be amended in the succeeding week's account current. Each station clerk should send up, likewise, his excess and deficiency-book weekly which will establish or impeach the accuracy of his cash account.

In the goods' branch of the audit department, every care and attention must be paid, that the interests of the company do not suffer by excessive deductions for tare, by negligence in weighing or measuring, by goods being conveyed of which no record is kept, and by goods being carried beyond their professed destination, or for less than the authorized rates. All these avenues of fraud should be carefully watched and rigidly controlled. The necessary arrangements to enable the audit-office to do this, and to fully check this important branch of traffic, will be sufficiently obvious, by attending to what we have said respecting the coaching department, and comparing it with the mode of working the goods' department, which we have before described. In fact, the value of any system of working the department of a railway, will be in no slight degree measured by the facilities it would present for exercising an efficient check in all its ramifications, both as to generalities and details.

In that branch of the audit department which embraces the sundries, the leading divisions will be, stores, treasurer's books, transfer and pay-bills. In the stores, the points to be ascertained are, that the person supplying the stores is paid for no more than he delivers, and at rates no higher

than the contract or current prices, the contractor in all cases being bound to furnish his accounts in a shape to be approved of by the company. The store-keeper should account periodically, either by issues or stock in hand, for all the stores delivered to him, and his statement of issues should be verified by the receipts from each department to which they have been supplied; his stock being taken at the same time, and the various receipts, issues, and stock being examined in each of the departments and out-stations throughout the line, the whole being compared with the store-keeper's accounts against the same places.

In the transfer division of the audit-office, the object to be attended to is simply, that each proprietor has a legal right to those shares which are assigned to him in the register. In the pay division there should be a properly authenticated list of all the officers and servants of the company furnished to the audit-office, together with a statement of their respective salaries and rates of wages. No alteration in these names or pay should take place without a specific notification to the audit-office, and no pay-bills should be passed which contain any sums not warranted by the standard list. It may, and indeed it will sometimes happen, that extra men must be employed for a short time for some specific purpose; when this is unavoidably the case, a separate pay-bill should be made out for them, containing their residence as well as name, with a certificate at the bottom from the head of the department, detailing the whole particulars of the occasion for which their services were required; and this should be countersigned by the secretary before it is allowed to pass the audit-office.

Finally, in auditing the treasurer's books, it will be necessary to see that all receipts and payments are properly entered and carried through the journal, ledger, cash-book, &c., that interest warrants are properly checked as to rate and time, that the dividends are properly apportioned, and that the balance sheet presents a true and faithful account of

the whole of the company's money transactions at the period of its date.

We shall next describe the arrangements necessary in case of fire. It is most material that these should be very clear and definite, yet it is strange how this subject is neglected, not only in railway stations, but in most, if not in all other large establishments. We have frequently been witness to accidents of this kind breaking out in factories, where three or four hundred hands have been employed, and the confusion was really painful to witness; every one running in all directions and defeating their own wishes by their very eagerness and zeal to be of use, yet hardly a man having any idea of what he ought to do; all giving orders, none obeying, and the fire in the meanwhile gaining strength enough to devour every thing on the premises, while the well-directed efforts of a dozen men, if they had been promptly applied in the first instance, would have crushed it with ease.

We shall first look at the means of extinguishing the fire, and next at the arrangement of the men belonging to the station. The former may consist, in the first case, of a head of water sufficiently high to be conveyed through hoses to all parts of the buildings, by means of pipes properly disposed. Another case will be, where fixed engines, if used, as they often are in principal stations, may be adopted to force the water through pipes and hoses where there is no sufficient head. Under either of these circumstances, all that is necessary will be to ascertain that the pipes are carefully protected from frost, by being laid at least two feet under ground, or by being surrounded by a non-conducting substance, such as charcoal or coke-dust, and that where they cross the lines of rails, they are led through an iron pipe large enough for a man to get through to do any repairs to them, which large pipe should be laid in concrete. (Plate CCCCXXIV. fig. 2.) This precaution should invariably be taken in all stations, so that the rails and water-pipes

can each be got at and repaired without disturbing the other.

Where there is neither a fixed engine or a sufficient head of water, the common fire-engine must be resorted to, and it will only be necessary to correctly ascertain that the hoses will lead to every part of the various buildings, for which purpose supply-cocks must be laid down in proper situations. The tank which fills the locomotive engines may also have hoses led from it. Every cock, and the connecting screws of each hose should be exactly alike, so as to fit indiscriminately in any part of the station, and the whole apparatus should be worked once a-week, and a written report of its state and condition sent in to the secretary or manager.

The next essential thing is to have in each room, office, workshop, and storehouse, or other department, a board hung up conspicuously painted with the words, "fire list" at the top. This board shews the order in which all the articles in that particular department ought to be carried into a place of safety, beginning, of course, with those of most value, or which may be likely to add to the power of the flames. Copies of all these boards should be hung up in the porters' room, so as to be constantly before their eyes. The stations of the men should also be painted and hung up, or, which is better, a large pasteboard should be framed with each station for the men printed on it, and the names should be written on slips, and slid into the pasteboard in columns, under their respective stations, by which alterations may at all times be readily made. Printed cards of the stations, fire lists, and fire directions, should also be in the possession of every man on the establishment, arranged for the night as well as the day, which they should invariably be called on to produce weekly when they receive their pay.

We shall now take for an example of the arrangement of the men, a principal station having at least fifty available hands on the ground, with only the common fire-engines, this be-

ing the most difficult case. There should be a fire-bell fixed, the sound of which should be markedly distinguishable from those usually rung to call the men together, or to give notice of the arrival of the trains. The fire instructions should direct every man and officer on the establishment to order this bell to be rung instantly they either suspect or discover a fire; it should, therefore, be situated close to a police station. The man who first gives the alarm (and who should always be rewarded) should tell the policeman where the fire is, and then as quickly as possible inform the sergeant of the divisions, and the head-officer of the company. When the bell rings, every man and officer should repair to the place where it is fixed, at which they will learn from the policeman the spot where the fire is suspected to be, unless the man who first discovered it, has informed them previously. Each, as they obtain the information, should proceed forthwith to their respective stations, placing themselves under their sergeants, who ought to endeavour to be the earliest on the spot.

The first fire division should consist of a sergeant and nine men, in two subdivisions of four and five each, one man, who may be called a corporal, having a subordinate charge of the four others in the second subdivision. Their post at the fire should be to clear a way to it, and direct their efforts to smother it if possible, by excluding the air and covering it with wet cloths ; they are also to play the water on it when the hoses of the engines are handed in to them. When the sergeant has ascertained the nature of the fire, if he finds the four men of his first division sufficient for the above purpose, he should then send the second subdivision, under its corporal, to assist the second division. The first division should be furnished with hatchets, pole-axes, crowbars, hammers, and wedges.

The second division, consisting also of a sergeant, corporal, and eight men, in two subdivisions, should be stationed to save the property. They should, therefore, com-

mence getting out every thing they can in the apartments most exposed to danger, in the order those things stand on the fire-list, delivering them into the charge of a policeman to be appointed for that purpose. If the nature of the case requires it, the sergeant of this division should send his second subdivision to remove carriages, or any other things outside; and if he requires more hands, he should send his corporal to the third division, who must aid him. The second division should be furnished with crow-bars and hammers; but if the iron cases we have recommended are made use of, these will not be necessary, and ropes long enough to lower such cases out of windows, or down stair-cases, will be all that this division will require for the offices.

The third divison should consist of three corporals, each having three men under him, and they should place themselves as a corps de reserve close to the entrance of the building where the fire is, but keeping out of the way of the second division, so as not to interrupt their labours. The second and third subdivision may, however, assist the second division in carrying the articles they bring out to a place of safety, but should on no account enter the building, unless their services are called for, in which case the first subdivision obeys the call, and the second subdivision leaves off assisting the second division, and places itself ready for the next call.

The fourth division, which may consist of all the remaining disposable men, should bring out and work the engines, fix the hoses, and hand them in to the first division. The fourth division, when requisite, should be reinforced from the first, second, and third divisions, as they can be spared; the third division, however, always keeping one subdivision at its post, whilst any of the first or second divisions are likely to want assistance. Two men from the fourth division should be appointed to bring all the fire-buckets, and one appointed to act as turn-cock.

The head officer of the company should be outside the

building where the fire is, superintending the third and fourth divisions, and regulating the general measures necessary to be taken. The second and third officers, or persons specially appointed for the purpose, should head the first and second divisions respectively. Junior clerks should be stationed as messengers with the first, second, and third officers, and one of these should be at each gateway to see none but proper persons are admitted. The first officer should alone be authorised to send for any assistance out of the station. The office door-keepers should admit none but the company's servants without orders. In the goods' station, one warehouseman should be nominated for the day, and another for the night, who should be able at any moment to point out where combustible articles are deposited, and the general order in which the goods should be removed by the second division. The fire-list for this purpose should be chalked on a black board.

The circumstances are so different under which such a heavy calamity as a fire may happen, and the arrangement of the buildings in railway stations are so variable, that we cannot pretend in our directions to go beyond general principles; but from the above draft which we have given, any person can form such a system as will suit the particular nature of the case in point. For instance, when the men are more or less than those which we have taken, the divisions should be proportionably increased or decreased; if there is a head of water or a fixed engine, the fourth division may be partly divided amongst the other three, and partly stationed with buckets. It will, however, be much the best plan to augment the third division, which is in reserve, leaving the first and second to apply to it when they want more help. The danger will be greater from having too many hands inside the building rather than too few.

At the out-stations along the line, the same plan may be pursued, modified according to the number of men, and when these are very limited, it will be advisable to provide

for additional help from the adjacent town. If this has not been done, and men have to be admitted indiscriminately to assist, they should be placed to work the fire-engine. In all cases care should be instantly taken that arriving trains have timely notice, that they may approach the station slowly.

With whatever care and judgment these fire arrangements may be made, it will be nearly all labour thrown away unless the men are thoroughly drilled into the system. They should be at first mustered at the fire-bell every day, and when well acquainted with their duties, a report of this should be made to the secretary or manager; when they are mustered by name, they should answer by calling out their division, subdivision, and duty. All the apparatus should then be tried, and any defects remedied, after which the whole should be returned to the appointed places. The superintendence of this duty should be confided to a competent and careful person, and the men should be stationed to the different divisions according to their strength, activity, and the skill they manifest, without the least reference to their usual duties.

The last department which we shall describe, is not the one which is of the least importance. It is that in which all the statistical details are wrought out; it deals in final quantities and prices, and in ratios. With the duties of this department, may be advantageously united the very essential branch of making and registering all experiments. The statistical details of railways are now becoming of such importance, that the government should undertake to publish them in a connected form. In the meantime, each company should, for their own sake, keep an exact register of them, to accompany their half-yearly reports. The Liverpool and Manchester company set an excellent example, in this respect, for several years, and it is to be regretted they have not continued to issue these valuable documents, in order that the degree in which the expenses lessened as the road

became consolidated, and the management of a new and unusual undertaking became better understood, might have been ascertained.

Nothing will tend more strongly to keep down the expenditure of railways than the free publication of these statistics; bad management must then become apparent, and the evil, once known, cannot fail to be remedied. It will be like the publication of the duty done by the steam engines in the Cornish mines; every one will be continually stimulated to keep pace with those companies who shew themselves to be the most efficient in their business; and the relative value of the respective managers will become apparent. At present we have no statistics for long lines. This state of ignorance, it is hoped, will not continue.

Numberless experiments are yet required to determine the laws which should govern railway practice; and by far the greatest portion of these could be conducted with but little, if any expense, beyond that of a mere registration of passing facts; the value of others, again, would amply repay the outlay which would be necessary in order to make them. Railways have now been in operation eight years, yet we have no generally recognised constant quantities applicable to their daily practice; friction, cohesion, power, consumption of fuel and water, wear and tear, expense of principal and secondary stations, cost of management, and many other equally important items, are all variously stated and in part assumed; so that new undertakings are, to a great extent, labouring in the dark for want of receiving that assistance which would be in all cases beneficial to both givers and receivers.

This department should be in operation from the first commencement of the railway, and during its progress should be employed in keeping an exact account of the state of the respective works; the quantity and price of all materials used in the construction of the railway; comparing these with the estimates; comparing the work done with

the time in which it ought to have been done ; keeping detailed accounts of each of the articles composing the permanent way ; testing all the rails as they are received, examining the merits of new inventions and improvements, and all other matters of a similar nature ; but when the railway is opened, the most arduous duties will commence, and we are satisfied railway statistics will never be placed on a proper footing, till government undertakes the business, and issues out printed forms to be filled up by each company.

The statistical department should be a confidential one, and no person except the principal should be able to arrive at final results. These should embrace every branch of expenditure, and should be made out and registered every month, and printed every six months ; being reduced, whenever it is possible, to the rate per passenger per mile, and per ton per mile, respectively, for passengers and goods; with the reasons for any increase or decrease. This periodical statement would be a powerful incentive to economy, and at all times it would be seen, whether or not the money expended preserved its proper ratio with the work done.

The statements which should be shewn by this department, would fall into two principal heads ; first, the expenditure and receipts, under the head of passengers and goods, in all their details ; and next, a classification of these details ; those cases where the expenditure is of a general nature, being dealt with accordingly. For instance, the maintenance of the permanent way should be apportioned between the coaching and carrying departments, in the ratio of the weights carried by each of those departments, and the relative velocities. The police, switchmen, gate-keepers, general office establishment, rents, taxes, interests on loans, &c., should be apportioned according to the ratio of profit in each department, this ratio being taken exclusive of those items.

The details should shew the expenditure in the coaching

and carrying office establishments, guards' wages, porters' wages, brakesmen's wages; expense of cartage, distinguishing horse keep; wages, repairs, &c.; duty on passengers, gas, water, oil, grease, tarpaulins, ropes, slings, &c.; for, in each case, the coaching and carrying departments separately. The general office disbursements, including direction, advertising, printing, law salaries, &c., all given separately. The maintenance of way, including engineers' and clerks' salaries, men's wages, cost of ballast, carriage of ditto, cost of repairs to permanent way, as well as that of relaying, the cost of new articles, &c. The locomotive expenditure should be shewn in coke, carriage, water, gas, wages to engine-men, firemen, labourers and mechanics, oil, grease, waste, tools, wood, iron, brass, copper, and the nature of the repairs; which should also be shewn in the coach and carrying repairs.

The number of miles travelled by the engines in each department; the number of tons of goods, gross and nett, carried one mile, classed according to the rates of carriage; the number of passengers carried one mile, the classes being distinguished; the weight of every train, the expenditure of fixed engines in detail, the cost of inclined planes, their gradients, velocity of the descent with definite weights and carriages, the flexure of rails and resistance to rolling, comparing the method by pendulum wheels with others; and, generally, every item of expenditure, under whatever class it may arise, which can lead to a comparison with that of other railways similarly circumstanced.

Having thus given every detail respecting the cost of working the line, the next step should be to classify them, so as to give the outlay per passenger and per ton per mile, under the several heads of coaching and carrying departments; the proper proportion of all the other items being placed against the coaching, or the carrying, as the case may be. It will then be desirable to give, per passenger and per ton per mile, respectively, the cost of porter-

age, police, coach repairs, waggon repairs, office expenses, locomotive power, and maintenance of way; coke, repairs, wages and water, as respects the engines, being given separately, as well as collectively; and the wages, ballast, carriage, materials and tools, in the maintenance of the way, distinguished in like manner, the whole being reduced to a series of tabulated forms, so as to present at one view, all the statistical facts connected with every operation on the whole railway.

It has been so repeatedly the case, that railway companies have frequently exceeded their estimates, and have consequently been obliged to resort either to borrowing money, or creating new shares, that it is necessary we should advert to the best way of their extricating themselves from any difficulty of this kind; although, if our instructions respecting the estimates are rigidly followed, we are certain it will but seldom happen that any measures of this kind need be resorted to; where, however, any unforeseen disasters have brought a company to the exigency of raising more money than they originally contemplated, the rule invariably should be, to borrow it, and never to create new shares.

This rule presumes, first, that the undertaking is in that estimation with the public, as to leave it perfectly optional with the directors which method they will put in execution; and, secondly, that the railway will properly pay when finished. When the risks, and the time which the original subscribers will in all cases lay out of their money are taken into account, we may take the minimum dividend in what would be considered a successful railway, at $7\frac{1}{2}$ per cent. It is clearly, then, the interest of the company to borrow any additional money they may want, as they can always have it at 5 per cent.; whereas, by creating new shares, they lessen this dividend and depreciate their original capital. A reserved fund should always be regularly set apart at every time a periodical dividend is declared, to be appropriated to the extinction of the debt.

Should there be any reason to suspect that the entire cost of the work will so far exceed the original sum contemplated, that the undertaking will not pay 5 per cent., then it would be both more prudent and more honest to create new shares to the amount required, issuing them at the fair market price, and giving the holders of the original ones the first offer. It may also be necessary, where the public confidence is not great in the success which may be expected to ultimately attend the traffic of the company, to combine the two modes, in order to shew that the proprietors themselves have a full and entire reliance on the advantages to be derived from the undertaking; but clearly, the more money borrowed, and the fewer new shares created, the more will the pecuniary prospects of the company be in a flourishing condition.

When money has been borrowed, another difficulty will in general arise, which seems to have escaped our legislators. Any act of Parliament authorising this to be done, is in general coupled with the conditions, that a certain portion, say half the original capital, shall have been paid up and expended on the works; and, further, that the interest of such sums borrowed shall not be paid out of the capital of the company, but out of their income. As this last condition cannot be fulfilled, for the very sufficient reason, that the company can have no income till their line is so far completed as to be at least partially open for traffic, there is no resource, and the act of Parliament must be violated, the interest must be paid out of the capital, and all that remains to be done, is to keep a fair and open account of all money so expended, and repay it in the best way in which it can be done when the returns from traffic do come in.

What are we to say, however, of those companies who continue to do this after they are in the receipt of an income? Who apportion that income amongst themselves, and quietly putting it in their pocket, still continue to pay the interest of their loans out of their capital stock, and even borrow

more money, in part to enable them to do so? and not only this, but who pay for their current expenses in the same manner; for instance, placing the repairs of the road, or, as it is termed, "the maintenance of the way," besides lesser things, to the head of "capital;" and while they are paying for them out of this fund, apportioning amongst themselves the money received from the traffic on that "way," under the name of a dividend.

As nothing which can minister to the comfort and convenience of the public, ought to be neglected, in the organization of a railway, not only as a payment due from these monopolies to the community at large, but as the readiest means of their producing a remunerating profit on the enormous outlay which is required for their construction in this country, means should be provided at each terminus where the passengers would be able to obtain every accommodation. In the usual course of things, the termini will generally be at some little distance from the towns, in consequence of the additional expense which would be incurred in the purchase of land, if they were taken to a more central situation. From the continual concourse of people at these termini, new buildings will gradually begin to thicken in that part of the town, and, in a few years, habitations will begin to embrace the railway station on all sides. Inns and shops will be amongst the earliest of these erections; still this will be a work of time, and will little accord with the impulse given to the mind by railway travelling.

It will therefore be highly advantageous, both to the proprietors of the railways and to the public, if the directors provide for the accommodation of the passengers, simultaneously with the opening of their railway. The expense will be small, and the profit may, with the utmost certainty, be reckoned on as equal to that of any other portion of their property. A building should therefore be erected on a convenient spot, adjacent to the principal stations, which should afford to each class of passengers the means of ob-

taining refreshments in that manner to which their habits and station in life have accustomed them. Such buildings would admit of considerable architectural display, and, if it should not in any case be thought advisable to include their cost in the general outlay, they may be a separate joint-stock speculation, the shares being offered, in the first instance, to the proprietors of the railway shares, as was done by the London and Birmingham railway company.

The centre of the building might form the hotel, where respectability should find every thing desirable in the coffee-room or small apartments, whilst luxury or moderation should be administered to in the larger ones. One wing detached from the hotel by a gate-way, might be unlicensed for wine or spirits, but affording all other refreshments, with beds, and sitting-rooms, if required. The other wing, likewise, detached by a gateway, might form the tap, where eatables and beds should at all times be at command. The one gate-way might form an entrance to, and the other an exit from the coach yard and stabling, where, according to the localities, post-horses, chaises, and hackney-carriages, &c., should be kept.

The hotel and each wing might be let, if desirable, to separate parties, the yard and stabling going with the hotel; or the whole might be farmed to one person; or they might be altogether worked by an agent on behalf of the shareholders. In each case, the charges for all the different species of accommodation should be defined and fixed up in every place except the bed-rooms, and their charges should invariably include all classes of servants. If this system is properly followed out, this difficulty would soon appear, namely, that such hotels, if near a populous town, would be filled with travellers of all descriptions, without any reference to the railway. We are convinced they would turn out most profitable speculations.

If we look back at the rapid progress which we have made in the science of locomotion during the last half-dozen

years, and at the degree of comfort and accommodation which, in conjunction with rapidity of transport, have been afforded to the public, at in most cases so very moderate a cost, the strides by which we have attained our present advanced position, are certainly sufficiently gigantic; but if we look forward, it requires but little of the gift of divination to perceive, that in a very few years more, a still greater change will take place, more particularly in the essential article of comfort. In a mode of transit so essentially new, and in which all our previous machines and appliances had to be completely reorganized, and numerous inventions of almost every kind were to be produced at a moment's call, to meet the various difficulties and wants which were continually arising out of such a novel mode of conducting the business of travelling in what may be called the wholesale way, it has been singularly fortunate, that in almost every instance, the various railway companies have kept on the safe side, that is to say, they have not done too much. They have erred on the best side they could commit an error on; they have been too cautious. It seems as if it required a certain time merely to travel at twenty miles an hour, and let the mind sober down a little before much else could be attempted. This feeling may now be rapidly expected to give way, and we shall find that as confidence is acquired, all the requisite arrangements will become consolidated in much more perfect and improved forms.

There is nothing now which ought to be more attended to by railway companies, than keeping their fares down; and this has in most instances been very much neglected. When parties possess such a complete monopoly as a railway, they should be particularly careful not to shew it. The expenses in many instances are certainly very great, and the companies have much to suffer in their progress through Parliament, and the rough grinding they have generally received from the rapaciousness of landowners. Accidents,

too, must happen, estimates will be exceeded, and these sources of expenditure must be met by a corresponding rate of price ; but when the railways are made, the feeling seems to be too general amongst some of these proprietors, that this is the moment for making reprisals upon the public for all losses, vexations, mishaps and mistakes.

In some cases railways have charged more for the carriage of passengers than the stages or mails did, trusting to beat them on the question of time only. In fact the receipts are great ; a certain sum must be set aside for a good dividend, and the rest is to be spent somehow or other. The same thing is observable in the statistics of the road trusts, many of them largely in debt, yet spending their money on fancied improvements, instead of getting out of debt, and then lowering the tolls.

The effect of this on travelling is fully shewn in the report of the Irish Railway Commission. For instance, the travellers from Brussels to Antwerp by railway in the year 1836 were 872,893, whereas those on the Liverpool and Manchester Railway for the same year were only 522,991, being the largest number for any year since the opening. Now, the population of Brussels, Antwerp, and Mechlin was 209,200, whilst that of Liverpool, Manchester, and Warrington was 486,812, considerably more than double, or the ratio of population was as 2·327 to 1, whilst that of the travelling was only as ·599 to 1. We must seek for the solution of this problem in the respective fares of the two companies. In the Liverpool and Manchester Railway, Mr. Pambour states, that there are 13 first-class trains to 16 second-class ; and as the last class hold most passengers, suppose we omit the mails, and say $\frac{13 \times 5{\cdot}5\text{s.} + 16 \times 4\text{s.}}{29} = \frac{135{\cdot}5}{29} = 4{\cdot}6724$ shillings, the average fare. We have no means of ascertaining the numbers on the Brussels railway, but if we take the dearest and cheapest, and compare them in the same ratio

as we did the others, we shall have $\frac{3{\cdot}50 \times 13 + 1{\cdot}20 \times 16}{29}$ $= \frac{64{\cdot}70}{29} = 2$ francs 23 cents per passenger on the average, or about 1·784 shillings, or 4s. 8d. in the one case, and 1s. 9¼d. in the other, or, allowing for the value of money in the two countries, about double the price; and this double price is accompanied with only one-fourth of the travelling, the ratio of population to that of travelling being very nearly 4 to 1. A still stronger case is that of the Paisley canal, where the fly-boat fare is 1d. per mile. Here, with a population of 262,725, the passengers in 1835 were 373,290, whilst in the same year, with a population of 486,812, the Liverpool and Manchester railway had only 473,849 passengers. The railway company from Paris to St. Germain's has tried the experiment of low prices with complete success; their greatest reduction of fares was at the station of Nanterre, where they were lowered from 7½d. to 5d., and the result was, that twelve days, ending the 4th December 1838, at the low fares, compared with twelve days ending November 22, at the high ones, shewed an increase of 839 passengers; and although the diminution in price was 34 per cent., the increase in the amount received was 16½ per cent. We therefore strongly recommend that fares should be moderate, or it will form the best plea in the world for the establishment of competing lines; and it should be remembered that railways will to a certain extent drive vans and waggons off the road, which were the ordinary vehicles for the travelling poor, and they ought to have a substitute, if it were merely an open box without seats. Soldiers are generally conveyed at 1d. each per mile, and their baggage at 3d. per ton per mile; this is less than half what is charged on some railways in second-class carriages.

The general system of working a line, which we have here laid down, is that which is adapted for a first-rate railway. On secondary lines it will perhaps be necessary to

place several of the departments under one person's superintendence, instead of having a head to each; but as this would be merely on the score of lessening expenditure, it should not be resorted to without there is a rigid necessity for it. On short lines this necessity will exist. When this is the case, one person might take the coaching department, goods' department, and the police, porters, and guards; the disbursement clerk might be dispensed with; one engineer might take the locomotive department, the construction and repairing department, and also the maintenance of the way, having good foremen in each case. But it is so much better to have a responsible head in every department, that we should always recommend that course to be adopted whenever it is practicable, that is to say, whenever the income of the company will allow it. It may, however, well deserve consideration, in every railway establishment, whether, at each of the stations of every kind, it would not save a considerable expense to have the porters, or a part of them, sworn in as police, so that they might on occasion act in either capacity. Attention to the number of entrance and exit gates, in planning out the stations, will also conduce to economy, as each of these will in general require an attendant policeman. There are numerous other means by which, in the middling and smaller class of railways, a moderate expenditure as well as a good arrangement, may be combined; but so much depends on the localities, together with the nature and extent of the traffic, that nothing definitive can be pointed out, except from a careful consideration of these; and the best step which the directors of all railways can take previous to forming any system whatever, is to consult a properly qualified and experienced person, both as to general principles and as to details.

LOCOMOTIVE ENGINES.

We now proceed to give a short account of the various improvements which have taken place in those locomotive engines which have been constructed with the especial intention of being used on railways. Our limits necessarily confine us in general to noticing only these, although several useful and ingenious arrangements, capable of being adapted, in some measure, to railroad locomotives, have been brought forward by Messrs. Gurney, Ogle, Summers, Clive, Heaton, Rowe and Boaze, Palmer, Wright, Burstall, Dr. Church, Colonel Maceroni, General Viney, Sir James Anderson, Sir George Cayley, Sir Charles Dance, and other persons who have long tried to introduce steam-carriages on common roads ; an attempt which we are certain will, at no very distant portion of time, be successful ; and which all sincere well-wishers to railroads should encourage by every means in their power. The unalterable laws of nature render it impossible that these carriages can, even for a moment, attempt to compete with railroads ; on the contrary, they may materially assist them, not only adding to their income, by feeding them from cross country roads at a cheaper rate than horse-coaches, and without the constantly-recurring impositions of coachmen and guards, but also by being another nursery for the mechanical genius which is now so rife on the subject of locomotion. Any improvement in the moving power of a steam-carriage on a common road, must be equally advantageous on a railroad, while the relative amount of friction which the two travelling surfaces present, must totally preclude the interests of their respective advocates from clashing in the slightest degree ; and whenever they have an opportunity, we would heartily recommend both parties to pull together.

The history of locomotives is inseparable from that of the high-pressure engine, first hinted at by the Marquis of

Worcester in his celebrated *Century of Inventions*, published in 1663, and brought into practical use by Savery, a captain (as they are called) in one of the Cornish mines, who, among many other things, proposed it for propelling carriages. The improvements of Newcomen in 1707, followed. Leopold, in 1720, produced the first high-pressure engine worked by a cylinder and piston. The term high-pressure, however, has long been limited to those engines which work by the force of steam alternately on each side of the piston, without any condensation; although the earlier engines did not do this, yet their steam pressure amounted in some cases to 40lbs. on the square inch.

After the magnificent improvements of James Watt, high-pressure engines were neglected for many years. With reference to locomotion, however, the next suggestion seems to have come from Dr. Robison, then a student in the university of Glasgow, who proposed, in 1759, the steam-engine to Watt as a means of moving wheel-carriages. Murdoch, in 1782, to whom Trevithick was a pupil, made a model of a steam-carriage, which was exhibited to many persons. In 1784, Watt explains, in his patent, the manner in which, among other things, he proposes his engine to propel carriages. This method, although a curiosity at the present day, bears the full impress of his mind. The boiler was to be of wooden staves hooped together with iron like a cask; the iron furnace was to be inside the boiler and almost entirely surrounded by the water, the whole being placed on a carriage, the wheels of which were to be worked by a piston, the reciprocating motion being converted into a rotatory one by toothed wheels and a sun and planet motion. His system of wheels was a double one, their proportions differing, and by this contrivance he proposed to overcome the variable resistance to be found on the road. The cylinder was to be seven inches diamenter, the number of strokes sixty per minute, and their length one foot. The carriage thus constructed was to carry two persons. Watt, however, never

built it, and continued to his death an opponent of high-pressure steam.

The first person who may properly be said to have reduced the theory to practice was Richard Trevithick, who seeing that lightness and portability were indispensable in any attempt at locomotion, either on common or on rail-roads, at once adopted the high-pressure principle. This was in 1802, when, in conjunction with Vivian, he took out a patent. The condenser, cistern, air-pump, and cold-water-pump were omitted, and the engine thus lightened, became not only considerably cheaper, but had the power to move itself, as well as to carry a load as a wheel-carriage. At first it was tried on common roads, and was exhibited before thousands of people; among other places, near Euston Square, where the London and Birmingham railway company's station is now fixed.

The carriage presented a handsome appearance, having two small wheels in front by which it was guided, and two large ones behind by which it was driven. It had but one cylinder, and this, together with the boiler and fire, which were all enclosed in a case, was situated low down and in the rear of the hind axle; each driving wheel could be worked separately, or one could be reversed while the other went forward, their motion being produced by spur gear, to which was added a fly-wheel. The piston-rod outside the cylinder was double, and drove a cross piece, working in guides, on the opposite side of the cranked axle to the cylinder, and the crank of the axle revolved between the double parts of the piston rod. To this axle was attached the first of the toothed wheels, and to the axle on which were the driving wheels was the other, similar in size to the first, and worked by it. The steam-cocks were opened and shut by a connection with the crank axle. The force pump, by which a supply of hot water, contained in the casing which enclosed the cylinder, fire-box, &c., was injected into the boiler, was also worked from it, as were the bellows

to produce sufficient combustion. The specification of his patent also adverts to contrivances for increasing the adhesion of the wheels, although they are said to be in general unnecessary; and it distinctly alludes to these engines being adapted for railroads.

Some writers have assigned to Trevithick the merit of inventing the steam blast up the chimney, which may be termed the life-blood of the locomotive engine. Trevithick has laurels enough, and has no need to borrow a single leaf from the crown of another. The steam blast was invented by George Stephenson, and used by him certainly prior to 1815, while in June 1815, Trevithick, so far from using the waste steam to increase the draft, took out a patent, in which, among other improvements, he included a method of urging his fire by fanners, similar to a winnowing machine.

In 1804, Trevithick took out another patent for a locomotive engine, in which he used a cylindrical boiler with flat ends, since called by his name. The fire door is near the chimney, and the furnace and flue is inside the boiler, the latter recurving and having its exit at the same end at which it entered. The cylinder is immersed in the boiler, all but a portion of the upper end, which is inclosed in a socket surrounded by the steam. In his first engine, the cylinder was horizontal, in the above it was vertical, and it is in this latter that the waste steam was thrown into the chimney. It is curious that such an able man as Trevithick should not have discovered the advantage of this; for although his exit pipe was not regulated so as to produce any thing near the maximum effect, either by its position or size, yet it must inevitably have increased the draught, although it is no less certain that he afterwards abandoned its use.

This engine was worked at Merthyr Tydvill in South Wales, a very indifferent tram-road. The wheels were plain, and were found to have ample adhesion. It drew ten tons of bar iron, together with the necessary carriages and its water

and fuel, at five miles an hour. It was not till a long time after this that any other considerable improvement took place, and an imaginary difficulty, perhaps, had no little effect in retarding the advance of locomotives: this was an idea which prevailed for some years, that adhesion between the wheels and the road was the thing wanted. There never was a greater mistake; it is found to be amply sufficient, and if not, can be had to an almost unlimited extent, by a galvanic action induced between the engine and the rails.

The next considerable improvement was in 1811, when a patent was taken out by Blenkinsop for the first double cylindered engine. The boiler was circular, having the fire door at one end opening into a tube in which was the furnace. This tube ran through the boiler, and making its exit, without any recurving, at the opposite end, was bent up to form the chimney. The cylinders were principally in the boiler; they were both vertical, eight inches in diameter, and their upper ends were outside the boiler at the top, where the eduction pipes met in a single tube, and threw the steam into the air. The piston rods, by means of cross heads, worked the connecting rods, which came down to two cranks on each side below the boiler, placed at right angles in order to pass their centres with certainty. These cranks worked two shafts, fixed across the engine, on which were small toothed wheels working into a larger one between them. On the axis of this, and outside the framing, were the driving wheels, one of which was toothed and worked into a rack on one side of the railway: there were two pair of plain flanged wheels, one before and one behind the driving pair, which ran on rails in the usual way. The weight of this engine was stated to be 5 tons, its consumption of water 50 gallons per hour, of coal 75lbs per hour, and it drew 94 tons on a level at $3\frac{1}{2}$ miles an hour, or 15 tons up 1 in 15; its maximum speed was 10 miles an hour, and its cost L.400.

The next patent was in 1812 to Messrs Chapman. Here the first mention of fanners to excite combustion occurs.

The motion was to be produced by having a chain passing round a barrel fixed to the engine. The chain was to be stretched along the railroad and made fast at each end, the barrel being set in motion by spur-gear. It had eight wheels, the boiler was Trevithick's ; it was tried at Heaton colliery, but did not succeed ; its weight was 6 tons, and it drew 54 tons up 46 feet in a mile, or about 1 in 115 at 4 miles an hour. This latter performance, however, was by an engine differing from the above ; the wheels were worked by spur-gear and not by the chain, and it could not start the above load without considerable slipping of the wheels, although it drew them when once in motion; hence 1 in 115 has been supposed the limit of adhesion with an engine weighing 6 tons ; this, however, is not correct. In these old engines, the adhesion had relation to the number of wheels, which in this case was eight. In the modern ones it had reference more to the manner in which the weight is distributed, the driving wheels always having, of course, the greatest proportion. Trevithick's engines were tried by Mr. Blackett of Wylam in 1813, and were worked by the adhesion of their wheels only. This was on a tram-way.

We now come to George Stephenson in 1814, whose first effort was the construction of an engine for the Killingworth colliery. This had two vertical cylinders, partly within the boiler and partly above it. This engine worked upon what is termed the second motion, that is to say, the connecting rods worked a middle axle communicating by means of spur-wheels to the main shaft, on which were the engine wheels ; these were four in number, and were fixed to their axles ; so the cranks, which were at right angles, turned two cogged wheels, and these gave motion to two others twice their diameter, fixed on the main axles. The cylinders were not so far apart as those in use at present, in order to give as much perpendicularity as possible to the connecting rods ; the middle cranks worked within the case of the engine; the chimney was cast iron, around which was a chamber extend-

ing back to the feed-pumps, for the purpose of heating the water previous to its injection into the boiler.

In order to neutralize as much as possible the shocks which this engine would meet from obstacles or inequalities on the road, as it had no springs whatever, the water barrel, which served as a tender, was fixed to the end of a lever and weighted; the other end of the lever being connected with the frame of the locomotive carriage, thus keeping up a vibratory motion on an uneven way. The boiler had one large tube in the centre, and rested on the carriage frame; but the lever apparatus was not found to compensate for the total absence of springs; and that it was inefficacious was of course soon discovered, by the machinery becoming deranged from the shocks. In fact, on this very engine the fate of locomotives may be said to have hung. It never made full steam enough to go more than about three miles an hour, and would have been condemned as useless had not Mr. Stephenson at last applied to it the steam-blast. This at once doubled the power of the engine, enabling her to go six miles an hour and maintain her steam. Even then this engine only ran about twelve months, and gave place at the end of that period to farther improvements.

The next locomotive constructed by Mr. Stephenson was that for which his first patent was obtained. This was taken out in February 1815, in conjunction with Mr. Dodd, and the alteration consisted in using a crank pin outside the driving wheels; one pair of which was worked by each cylinder; the crank pins being kept at right angles by means of an endless chain working round wheels fitted with cogs to receive the links. These wheels and the chain superseded the use of spur-gear, which had been found objectionable, and this engine worked well. It had a third pair of wheels between the two driving pair.

In June 1815, Trevithick took out another patent, in which he proposed fanners consisting of "flat plates or leaves," revolving in a case, which were to "produce a cur-

rent of air in the manner of a winnowing machine, to blow the fire." He also in the same patent proposed to "place in the flue a screw or set of vanes, somewhat similar to a smoke-jack," which were to "revolve by connection with the steam-engine, for the purpose of creating an artificial draft in the chimney." Similar contrivances to these were afterwards claimed by Lord Cochrane and Mr. Galloway, and also by Messrs. Braithwaite and Ericson. The former contrivance, namely, fanners revolving rapidly inside a circular drum, has been lately used with success as a most powerful blowing machine for iron furnaces, and other works requiring a very intense heat; yet the invention is nearly 200 years old, and at so remote a period it appeared in print with explanatory engravings. One kind of tubular boilers had long been known, and were used by Trevithick; being in this patent stated as a part of his apparatus, although he only claimed a modification of them. They were vertical, and contained water, not fire or hot air, like those of a recent construction.

The next patent was in 1816 to Messrs. Stephenson and Locke, with which the improvement of Stephenson and Dodd was incorporated. This patent extended to railways, carriage wheels, and several other useful matters connected with the same subject, and among other things the following contrivance was introduced. The weight of the engine rested on steam-springs by means of three pair of small cylinders, fixed to the lower part of the boiler, and open to the inside of it, in which they entered for several inches. These cylinders were also open at the bottom, and a piston rod, with a solid piston, worked in them: the lower end of these piston rods, after passing through a hole in the framing of the engine, were fixed to the working cods, over the axle of the wheels; hence any oscillation in the carriage of the engine was transferred to those pistons, which acting against the pressure of the water, or more properly speaking, of the steam, performed the office of springs; hence the steam

supported the weight of all the machinery, except that which was connected with the framing. The furnace in these engines was contained within the boiler; the door of it opening at the opposite end to the chimney, and not at the same end like Trevithick's.

In the above engines, the second motion or spur gear was also discontinued, and the endless chain used instead. They had six wheels, and worked with cranks, like the present ones. The metal, or cast-iron chimney, and heating apparatus, was also set aside. The six wheels were continued in use as long as the steam-springs were applied, and when steel ones were adopted they were again reduced to four.

The opinions which were then entertained respecting the improvements that were destined in a short period, to effect a complete revolution in all our ideas of time and space, as far as they relate to travelling, may be gathered from what Mr. Galloway says in his *History of the Steam-Engine.* "These locomotive engines have been long in use at Killingworth colliery, near Newcastle, and at Hilton colliery on the Wear, so that their advantages and defects have been sufficiently submited to the test of experiment; and it appears, that notwithstanding the great exertions on the part of the inventor, Mr. Stephenson, to bring them into use on the different railroads, now either constructing or in agitation, it has been the opinion of several able engineers, that they do not possess those advantages which the inventor had anticipated; indeed there cannot be a better proof of the doubt entertained regarding their utility than the fact, that it has been determined that no locomotive engine shall be used on the projected railroad between Newcastle and Carlisle, since, had their advantages been very apparent, the persons living immediately on the spot in which they are used, namely, Newcastle, would have been acquainted therewith.

"The principal objections appear to be the difficulty of surmounting even the slightest ascent, for it has been found, that a rise of only one-eighth of an inch in a yard, or of

eighteen feet in a mile, retards the speed of one of these engines in a very great degree, so much so indeed, that it has been considered necessary, in some parts where they are used, to aid their ascent with their load, by fixed engines, which drag them forward by means of ropes coiling round a drum. The spring steam cylinders below the boiler were found very defective, for in the ascending stroke of the working piston, they were forced inwards by the connecting rod pulling at the wheel in turning it round, and in the descending stroke the same pistons were forced as much outwards; this motion or play rendered it necessary to increase the length of the working cylinder as much as there was play in the lower ones, to avoid the danger of breaking or seriously injuring the top and bottom of the former, by the striking of the piston, when it was forced too much up or down."

Several patents were now taken out, proposing various modifications of tubular boilers, the tubes containing the water, and other contrivances, mostly adapted to steam-carriages on common roads. So late as October 1825, a new form of racked rail formed the subject of one of them; in this it was proposed to be in the middle of the railroad, which was to be composed of masonry. In 1826, Mr. Robert Stephenson, senior, proposed an ingenious method of obviating the friction between the flanges of the wheels of a locomotive engine and the rails, by having a separate axletree to each wheel, so that they might revolve independently, and at different velocities. By another plan, in the same patent, he proposed to allow one end of each axletree to move in a ball and socket joint, while the other, the wheel end, instead of revolving in a circular aperture, was to have a motion up and down in a vertical slot, so as to accommodate itself to the inequalities of the rails. Mr. Chapman, in 1827, took out a patent for a similar purpose.

The obstacles which Mr. Stephenson encountered in his attempt to bring locomotives into general use, may be easily

conceived by what took place when the Liverpool and Manchester railway drew near its completion. An inquiry was there instituted into the comparative merits of fixed and locomotive engines, and in the spring of 1829, Messrs. Walker and Rastrick, engineers, were commissioned by the directors of that line to examine into both modes on the existing railways, and report on their relative advantages; for which purpose they were furnished with a section of the road, the greatest inclination, except where fixed engines were necessary, being 1 in 880, and also with an estimate of the expected traffic between Liverpool and Manchester, which was stated to be daily as follows:—

From Liverpool to Manchester.

	Gross weight. Tons.
1000 tons goods	1500
500 ... cattle, sheep, &c.	750
400 ... coal, 12 to 15 miles	600
800 empty waggons, 8 to 20 miles	800
300 passengers in 35 carriages	100
Gross tons daily	3750

From Manchester to Liverpool.

	Gross weight. Tons.
500 tons goods	750
300 empty waggons	250
200 do. coal waggons, 12 to 15 miles	200
1600 tons coals, 8 to 20 miles	2400
250 empty cattle carriages	250
800 passengers in 35 carriages	100
Gross tons daily	3950

The following are Messrs. Walker and Rastrick's estimates:—

One engine	L.550
Tender..........................	50
One-fifth for spare ones	120
Total...	L.720 per engine.

Annual repairs	L.107	8	0
Fuel, 382 tons coals, at 5s. 10d.	111	8	4
Wages, grease, hemp, &c.	92	12	0
Average charge for capital annually	55	16	0
Total working cost for 312 days	L.367	4	4

The charge on capital was taken on the presumption of the engines lasting 20 years, or 12½ years' purchase, after deducting for old materials L.60, recoverable in 20 years' time, equal to 36s. present money.

The capital required would therefore be 123 engines and tenders, each drawing 13 tons L.73,800

Fixed engines for Rainhill and Sutton inclined planes	9,190
Ropes for Do.	792
Duplicates of engines	400
Do. ropes	962
Iron crossings	120
Signals for Rainhill and Sutton planes	100
10 water stations, at L.560 each	5,600
Total...	L.90,964

The annual cost for working the whole was estimated thus:

102 engines constantly at work, at L.367, 4s. 4d. each	L.37,456
Stationary engines at Sutton and Rainhill	5,013
Water stations, annually	923
Carry over....................	L.43,392

	Brought over	L.43,392
Level crossings	L.120	
Duplicates of engines	400	
Do. ropes	961	
Signals	100	
	1581 at 5 per cent	79
	Interest of capital and annual expenditure	L.43,471

Messrs. Walker and Rastrick estimated the fixed engine mode of doing the same work as follows, including engine houses, &c.:—

1 30-horse engine at the Liverpool tunnel	L.2,000
2 60-horse do. for Sutton and Rainhill planes	10,000
6 20-horse do. at 3 stations, two at each to work at the foot and middle of the flat on the top of the planes	8,130
15 stations, $1\frac{1}{2}$ miles apart, with 2 30-horse engines at each	52,500
2 12-horse engines at the Manchester end	1,725
Sheaves, 13090, at 8 yards apart, at 15s. each, fixed	9,817
Extra foundations for engine-houses, &c. at Chat-moss	3,000
Total	L.87,172

The amount of capital for fixed engines would therefore be

Cost of engines, &c.	L.87,172
Duplicates of Do.	1,354
Ropes	5,187
Crossings	300
Duplicate ropes	6,299
Signals	550
Total capital	L.100,862

The annual expenditure was taken to be as follows:—

Interest of capital 5, and depreciation $1\frac{1}{2}$ per cent.	L.5,666
Repairs, coals, and working expenses..........	11,258
Ropes..	11,232
Do. on Sutton and Rainhill planes..............	3,316
Tail ropes on ditto....................................	312
Interest on spare ropes..............................	220
Sundries...	1,291
	L.33,295

From these estimates it appeared, that the locomotive would cost L.10,458 less in capital than the fixed engine plan, but that the annual expenses would be L.10,147 more, and that the rate of carriage would be as 7 to 9 in favour of stationary engines, being ·2784 of a penny per ton, per mile, on the locomotive, and only ·2134 of a penny on the stationary engine plan; and after the most careful examination into all the branches of expenditure, and also the power and capabilities of the locomotive engines, as they stood at that day, Messrs. Walker and Rastrick reported to the directors of the Liverpool aud Manchester Railway Company that, "upon the consideration of the question in every point of view, taking the two lines of road as now forming; and having reference to economy, dispatch, safety, and convenience, our opinion is, that, if it be resolved to make the Liverpool and Manchester Railway complete at once, so as to accommodate the traffic as stated in your instructions, or a quantity approaching to it, the stationary reciprocating system is the best." They also stated that, if it was only intended to proceed by degrees, proportioning the power of conveyance to the demand, in that case, they would recommend the use of locomotive engines.

As it was absolutely necessary that the railway should be made complete at once, this opinion was tantamount to a condemnation of locomotives. Messrs. Robert Stephenson and Locke, therefore, on the publication of the report in

question, undertook its examination as to the correctness of the various deductions which were laid before the directors; and the different statements which they produced, arising, in a great measure, from improvements made by Mr. Stephenson in his engines, since Messrs. Walker and Rastrick formed their estimates, fortunately for the world turned the scale the right way.

Messrs. Robert Stephenson and Locke assume the power of each locomotive to be 30 tons gross, or 20 tons nett, conveyed 90 miles daily, or three trips between Liverpool and Manchester, at 12 miles an hour, being equivalent to 1800 tons nett, or 2700 tons gross, conveyed one mile, and their calculations were based on the following data.

On the Stockton and Darlington railway, where the average inclination is 1 in 246, but which is in some places level, and in others, has an inclination of 1 in 100, the engines were drawing 20 loaded waggons, weighing 80 tons, making, with the engine and tender, which weighed 12 tons, a total of 92 tons on a level, and 20 empty waggons, weighing 25 tons, or a total of 37 tons, including the engine and tender, up 1 in 100, at 4 miles an hour. The resistance from every cause, except gravity, which was taken at $\frac{1}{200}$th, or rather more than 11 lb. per ton, gave $\frac{92 \cdot 2240}{200}$, or 1030 lbs., as the maximum resistance at 4 miles an hour, and $\frac{1030 \cdot 4}{10} = 412$ lbs. as the power required at 10 miles an hour with the loaded waggons, and $\frac{37 \cdot 2240}{200} = 414$ lbs. friction, plus $\frac{37 \cdot 2240}{100} = 828$ lbs. gravity, or a total of 1242 lbs. for the resistance with the empty waggons, whence $\frac{1242 \cdot 4}{10} = 497$ lbs. was taken as the power required at 10 miles an hour.

On the Springwell railway, averaging 1 in 222, and varying from 1 in 80 to 1 in 280, one engine took $22\frac{1}{2}$ gross tons, or, including engine and tender, 33 tons, at 6 miles an hour, whence gravity being 606 lbs., and friction 370 lbs., $\frac{976 \cdot 6}{10}$, or $585\frac{1}{2}$ lbs. was taken for the power required for this load at 10 miles an hour; and for the occasional effort required up 1 in 80, there would be gravity, 924 lbs.; friction, 370, or $\frac{1294 \cdot 6}{10} = 776$ lbs.

On the Bolton and Leigh railway, the Lancashire Witch engine took 58 tons up 1 in 432, at 8·8 miles an hour, which is equal to 836 lbs. at 10 miles an hour.

On the Liverpool railway, the Rocket travelled both ways with $37\frac{1}{4}$ tons, at the rate of 13 miles an hour, and another engine employed on the works leading marle, took 70 tons, exclusive of its own weight, at 5 miles an hour; hence 20 tons nett, at 12 miles an hour, requiring a force of 497 lbs., was considered a fair allowance for the performance of locomotives at that time on the Liverpool and Manchester railway, except on the steep planes, where an assistant engine was proposed to be used.

We then have L.720 as the cost of one engine and tender, including one-fifth for spare ones.

Interest of capital, including depreciation of L.720, at $7\frac{1}{2}$ per cent	L.54
Engine-man's wages, 21s. per week, and fireman, L.26 per annum	81
Grease, oil, hemp, &c.	12
429 tons of coal per annum, at 5s. 10d.	128
Annual repairs	50
Total cost of one engine for 312 days	L.325

The item of coals was determined from the following data:

	lbs. coal per ton per mile.
Experiments on the Killingworth engines.........	·213
Do..	·205
Do..	·160
Do. on Darlington engine with a double tube.....	·160
Do. on Lancashire Witch engine..................	·173

hence ·175 lbs. per ton per mile was taken for 1800 tons per day, or 3150 lbs. of coals per day, or 439 tons in 312 days.

The cost of repairs to the engines, was taken from that of the engines called the Springwell and Darlington, for two years, viz.

1827.	Wright-work....L.	10	15	5	2 engines one year.
...	Smith-work.........	40	17	3	
...	Sundries............	50	2	0	
1828.	Wright-work........	4	3	2	2 engines one year.
...	Smith-work........	22	15	0	
...	Sundries............	31	17	6½	
...	Fire bars...........	27	8	3	
1829.	Four of the Darlington engines..	154	8	0	4 engines one year.
...	Do. fire bars.......	24	0	0	
		L.366	6	7½	
Deduct old materials		9	19	3½	
Cost in repairs of 8 engines one year.		356	7	4	
Annual cost for each engine................		L.44	10	11	

The interest of capital, and annual expense of working the whole line with locomotives, was estimated as follows:

One engine taking 1800 tons 1 mile, and the daily traffic being 4000 tons 30 miles, or 120,000 tons 1 mile, requires 67 engines.....	L.21,751
10 assistant engines for the inclined planes......	3,246
Annual cost of five water stations................	520
	L.25,517

The water stations were taken at L.500, and $7\frac{1}{2}$ per cent. interest and depreciation on this gives.......	L.$37\frac{1}{2}$
Annual repairs, grease, &c..............................	5
Coals, 100 tons at 4s. 6d..............................	$22\frac{1}{2}$
Attendant..	39
Annual total..........................	L.104

The amount of capital required for the locomotive system would be as follows:

$67+10+\frac{7}{5}{}^{7}$ engines and tenders, or 93 at L.600	L.55,800
4 water stations at L.500..........................	2,000
Crossings at the planes for assistant engines to go on both lines..................................	200
Total capital for locomotive system...............	L.58,000

Messrs. R. Stephenson and Locke estimated the stationary engine system to cost as follows:

Dividing the distance into the same number of stages as Messrs. Walker and Rastrick, the power required was estimated to be,

1 40-horse engine at the Liverpool tunnel........	L.1,800
34 40-horse do. at 17 stations, including the planes, at L.2,100................................	71,400
4 25-horse engines at two stations at the bottom of the planes, at L.1440........................ ...	5,760
Carry over..................	L.78,960

Brought over	L.78,960
2 24-horse engines at the station on the top of the planes, at L.1440	2,880
1 24-horse engine at Manchester	1,890
13,090 sheaves for ropes at 12s.	7,854
4 set of crossings and turn-outs at each station, or 88 at L.50	4,400
Stationary engines, total expense	L.95,984

The power of the engines on the $1\frac{1}{2}$-mile stages was estimated thus:

	lbs.
Friction of 52 tons at $\frac{1}{200}$	582
Do. of $1\frac{1}{2}$ miles of $4\frac{1}{2}$-inch rope, weighing 6888 lbs. at $\frac{1}{12}$th	574
Total	1156

The power of a horse being taken at 12 miles an hour, as equal to $\frac{150 \cdot 2\frac{1}{2}}{12} = 31$ lbs., then $\frac{1156}{31} = 37$ horses, or allowing for spare power, say 40 horses for one line. The other stations were estimated in the same manner.

To ascertain the friction of the rope, a number of waggons were let down an inclined plane, till they were found to draw out a given length of rope, at a uniform velocity: for instance, on a plane of 1 in 33, four waggons weighing 96 cwt., drew 1370 yards of rope, weighing 5004 lbs., at the rate of $1\frac{1}{2}$ miles an hour, then

Gravity of the waggons	326
Do. of the rope	152
	478
Deduct friction of the waggons	52
Friction of the rope	426 lbs., or nearly $\frac{1}{12}$th its weight.

The cost of the engines were estimated as follows:

One engine of 80, or two of 40-horse power......	L.2,800
Four rope rolls, and machinery......................	550
Engine-house, and chimney..........................	650
Dwelling-house, reservoirs, &c......................	200
	L.4,200

Seventeen stations at L.4,200=L.71,400.

The interest of capital and annual expenditure of the stationary engines, Messrs. Stephenson and Locke estimated as follows:

Interest and depreciation at 6½ per cent on L.95,984..	L.6,239
Coals, repairs, and working expenses................	18,917
Ropes...	16,137
Duplicate ropes, and interest of value upon.........	739
Total annual expenditure on stationary engines...	L.42,032

In the above, the second item is composed thus:

Coals for 1572 horses' power, 10 hours per day, 312 days, at 17 lbs. per horse per hour=37,222 tons at 4s. 6d................................	L.8,375
Repairs, oil, hemp, &c., at L.1 per horse per annum..	1,572
43 engine-men at L.54, 12s..........................	2,348
21 assistants at L.40.................................	840
42 brake-men at L.40.............	1,680
84 men to ride the trains, or one for each rope, at L.40..	3,360
Wear of sheaves, at L.8 per mile of double way	240
Oil for sheaves, 2100 gallons, at 2s. 6d...........	262
8 men to oil sheaves, at L.30........................	240
	L.18,917

The wear of ropes, the third item, is taken as follows:

108 miles of $4\frac{1}{2}$-inch rope on the level stages, $221\frac{1}{3}$ tons, which, after deducting the value of old, is L.42 per ton	L.9,296
6 miles of $5\frac{1}{2}$-inch head-rope for the inclines $19\frac{1}{10}$ tons at L.42	802
6 miles of $3\frac{1}{2}$-inch tail-rope for the inclines, 7 tons 17 cwt. at L.42	330
30 grooves for the ropes crossing the road, at L.10,	300
	L.10,728

Interest on L.10,728, at 5 per cent	L.537
Wear, say 30 miles, at one-tenth of a penny per ton per mile on 4000 tons daily	15,600
	L.16,137

The last item, the duplicate ropes, is estimated thus:

108 miles of spare $4\frac{1}{2}$-inch rope, at L.51	L.11,288
6 miles of $5\frac{1}{2}$-inch head-rope	974
6 miles of $3\frac{1}{2}$-inch tail-rope	400
Duplicates for engines at L.1 per horse power	1,572
22 signal-stations at L.25	550
	L.14,784

Interest on this amount at 5 per cent., L.739.

The following is Messrs. Stephenson and Locke's estimate of the amount of capital required for stationary engines:

Estimated before	L.95,984
Ropes in use	10,728
Duplicate ropes and machinery	14,784
Total	L.121,496

Hence it appeared, that the locomotive system would cost L.63,496 less than the stationary, and L.16,514 per annum in working expenses. We shall place the two results of these different estimates together, as forming a record of no ordinary interest, now the one system has so completely been established as totally superior to the other, except on very short lines.

System.	Capital.		Annual expense.		Cost per ton per mile.	
	Walker and Rastrick.	Stephenson and Locke.	Walker and Rastrick.	Stephenson and Locke.	Walker and Rastrick.	Stephenson and Locke.
	L.	L.	L.	L.	d.	d.
Locomotive engines,	90,404	58,000	43,464	25,517	0·2786	0·164
Stationary ditto	100,862	121,496	33,317	42,032	0·2135	0·269
	10,458	63,495	10,147	16,515	0·0651	0·105
Locomotive system,	Less.	Less.	More.	Less.	More.	Less.

The policy of employing locomotives, even if they had been the dearest instead of the reverse, would be perfectly apparent from Messrs. Stephenson and Locke's statement, which is thus confirmed by Mr. Walker's opinion in his report: "In considering the long chain of connected power of the stationary engines, given out by so many machines, with the continual crossings of the trains from one line to the other, and subject to the government of no less than 150 men, whose individual attention is all requisite to preserve the communication between two of the most important towns in the kingdom, we cannot but express our decided conviction, that a system which necessarily involves by a single accident the stoppage of the whole is totally unfitted for a public railway."

After well considering these reports and the observations made on them by Mr. Stephenson, the directors took the wisest step which they could possibly have taken; and this was, to offer a premium of L.500 for the best locomotive engine, which should draw on a level plane three times its

own weight at ten miles an hour, which weight was not to be more than 6 tons. The price of the engine was restricted to L.550; the height of the chimney to 15 feet; the pressure on the boiler to 50 lbs. per square inch. It was to consume its own smoke; the whole weight of the engine and boiler was to be supported on springs; and, if this weight exceeded 4½ tons, the engine was to have six wheels. The premium was offered in April 1829, and the trial was to take place in October of the same year. It is from this point we may date, with the exception of the steam blast, the era of modern locomotion on railroads.

The engines entered for the competition, were as follows:

Engine.	Maker.
Rocket................	Robert Stephenson.
Novelty.................	Braithwaite and Ericson.
Perseverance..........	Burstall.
Sans Pareil..............	Hackworth.
Cyclopede..............	Brandreth.

The latter was a horse-locomotive, and was therefore not considered as entitled to run for the prize. It was tried, however, as a matter of experiment, but its speed was only about six miles an hour. After a short trial, the Perseverance was withdrawn by its proprietor. The competitors were consequently reduced to three; viz.

	Engine weight.				Drawn weight.				
	tons	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	
Rocket........	4	5	0	0	3	4	0	2	...tender.
					9	10	3	26	...two carriages.
					12	15	0	0	
Novelty......	1	18	2	19	5	16	0	0	
Sans Pareil....	4	15	2	0	3	7	3	0	...tender.
					10	19	3	0	...three carriages.
					14	6	2	0	

The Novelty carried its own fuel and coke, without any tender. The ground chosen for the trial was on the Manchester side of Rainhill Bridge, about nine miles from Liverpool, where the railway is on a level. The Sans Pareil being over the weight, was tried only as an experiment, and was found to draw twenty tons at fifteen miles an hour; the fuel consumed was, however, very great.

The Novelty likewise had to be withdrawn, through a series of unfortunate accidents, which had no reference to the character or capabilities of the engine; and we well recollect, that it made a powerful impression on the public mind at the time. On the first day of trial, Thursday, October 6, 1829, it went twenty-eight miles an hour (without any attached load), and did one mile in seven seconds under two minutes. This performance will now appear trifling, but at the time the sensation produced was immense. Mr. Nicholas Wood, who was appointed one of the judges on the occasion to award the premium of L.500, had, even after the opening of the Stockton and Darlington railway, published his opinion respecting locomotives as follows: "It is far from my wish to promulgate to the world, that the ridiculous expectations, or rather professions of the enthusiastic speculatist, will be realized, and that we shall see engines travelling at the rate of 12, 16, 18, or 20 miles an hour. Nothing could do more harm towards their adoption or general improvement, than the promulgation of such nonsense." And that the directors of the Liverpool and Manchester railroad in some measure agreed with this opinion, may be inferred from their appointing that gentleman as an umpire, and only requiring the engines to travel with three times their weight at ten miles an hour.

On the second day's trial, the Novelty drew 11 tons, 5 cwt. at $20\frac{3}{4}$ miles an hour, but, unfortunately for the owners, some of the tubes gave way at the joints during the succeeding trials, and the competition was given up, thus leaving a clear course open to Mr. Robert Stephenson's

Rocket, the performance of which we have now to state, first premising that Robert Stephenson, (a brother of George Stephenson) we have often heard erroneously mentioned as the individual who made the Rocket: it was made by his nephew, the engineer of the London and Birmingham railway. Mr. Robert Stephenson, sen. was not an engine-maker.

The Rocket was the only engine which performed the required distance of 70 miles, with the given load, and at the stipulated speed. Without a load it went at the rate of 30 miles an hour, and when drawing three times its weight, at upwards of 24 miles an hour. It completed the first 35 miles in three hours and ten minutes, being upwards of 11 miles an hour; and after taking in a fresh supply of water, it performed the second 35 miles in 2 hours 52 minutes, being at the rate of upwards of 12 miles an hour; and this speed, it must be remembered, included all the stoppages at each end of the trial ground, which was $1\frac{3}{4}$ miles long: 1-8th of a mile was allowed at each end for getting up the speed and stopping the train, but this advantage is not included in the above. Had the 70 miles been in one length, it is judged the Rocket would have maintained an average velocity of at least 15 miles an hour. The coke consumed was 142 lbs. in getting up the steam, and 1085 lbs. in running the 70 miles, and 579 gallons of water were used. This trial of the Rocket took place on October 8, 1829.

The Rocket was constructed with four wheels not coupled; its boiler was six feet long and three feet in diameter, and contained twenty-five copper tubes three inches in diameter, through which the heated air from the furnace passed in its way to the chimney. The furnace, which was at the after end of the engine, was two feet wide and three feet high, and had an external casing, between which and the fire-box there was a space of three inches filled with water, and communicating with the boiler. The cylinders were

placed on each side of the boiler in an angular position, one end being nearly level with the top of the boiler at its after end, and the other pointing towards the centre of the foremost or driving pair of wheels, with which the connection was made from the piston-rod to a pin on the outside of the wheel. The tender was four-wheeled, and similar in shape to a waggon ; the foremost part holding the fuel, and the hind part a water-cask, which primitive plan is still adhered to on the Stockton and Darlington railway. The blast was produced by steam, the eduction-pipe leading into the chimney. On the day of the trial, this engine was managed by Mr. James Stephenson, an uncle of the maker.

The only other engine requiring any particular notice, was the Novelty, by Messrs. Braithwaite and Ericson. This engine carried its own water and coke without any tender, and the leading feature belonging to it was, its lightness and handsome appearance. The whole weight of the engine, without water and coke, was only 2 tons 15 cwt., and deducting from this 16 cwt. 1 qr. 9 lbs. for the weight of the tank, coke baskets, water and fuel for a journey of thirty-five miles, left the nett weight of its working power only 1 ton. 18 cwt. 2 qrs. 19 lbs., while the engines in use on the Stockton and Darlington railway at this time weighed 12 tons. It had four coupled wheels, the boiler held about 45 gallons of water ; the cylinders were 6 inches in diameter, with a 12-inch stroke.

The boiler, a cylindric one, was placed under the engine frame ; at one end was the furnace surrounded with water, and fed with fuel by means of a hopper passing through the steam chamber, which was over the furnace. The heated air went along a flue, making three bends backwards and forwards in the boiler, and this flue was made gradually less and less till it terminated in the escape-pipe. The blast was obtained by bellows which threw a strong current of air in at the bottom of the furnace. The connecting rods were moved by means of bell-cranks joined by slings to the piston-rod.

The prize of L.500 was, as a matter of course, awarded to Mr. Robert Stephenson for his engine, the Rocket. Prior to this competition, the greatest loads which were drawn by locomotives was $43\frac{1}{4}$ tons gross, engine and tender included, 15 tons at ten miles an hour, or $28\frac{1}{4}$ tons of goods, including waggons, while the Rocket, in November 1829, weighing only $7\frac{1}{2}$ tons, drew 44 tons gross, at 14 miles an hour, being, exclusive of engine and tender, $36\frac{1}{2}$ tons of goods and carriages; or, in round numbers, the Rocket, only half the weight of the best drawing engine previously constructed, drew one-third more load at one-third more velocity. The principal improvement which led to this great result was, the introduction of tubes in the boiler, by which the evaporating power was increased to three times that of the older engines, with 40 per cent. less consumption of fuel. These tubes were suggested by Mr. Booth of the Liverpool and Manchester railway; the original inventor, however, was M. Seguin, whose patent is dated February 22, 1828, whereas the Rocket was not brought out till October 6, 1829. M. Seguin had never succeeded in getting them tight, through the expansion of the materials. Mr. Robert Stephenson, who made several engines for M. Seguin, effected this by hooping them inside, by which means the expansion closed them perfectly.

The engines in the above trial having been limited as to weight, it was immediately perceived that further improvements would result from increasing this, and expending the addition as much as possible in enlarging the evaporating powers of the engines. Hence the boilers have been made much larger, the number of tubes increased, and various other arrangements made conducive to that result, and by these means, the weight of the engines have been brought up by degrees to what they are at present. The number of tubes in the Rocket was 24, and their diameter three inches; the Meteor had 88 of two inches diameter; the Comet, Arrow, and Dart, 90 each of the same diameter; while the Northumbrian had 132 of $1\frac{5}{8}$ diameter.

The highest number of tubes we know of in the English engines, is 169, which were tried in an engine built by Mr. Robert Stephenson for the Grand Junction Railway. The Planet, which was the ninth engine built by Mr. Stephenson for the Liverpool and Manchester railway, had 129 of $1\frac{5}{8}$ inches diameter. The Rocket had an 8-inch cylinder, and 18-inch stroke; her boiler was 6 feet in length, and 3 feet in diameter; the area of her tubes exposed to the heated air was 113 square feet; her driving wheels were 4 feet 3 inches in diameter, and the smaller pair 2 feet 7 inches. The Planet had an 11-inch cylinder, and 16-inch stroke; the boiler was $6\frac{1}{2}$ feet long, and 3 feet in diameter; the four wheels were 5 and 3 feet in diameter, and the surface of the tubes 370 feet, besides $37\frac{1}{4}$ square feet of surface exposed to the direct action of the fire. This latter has varied in different engines up to $108\frac{1}{4}$ square feet, and the area of the tubes has been as much as 641 square feet.

The wear of tubes, and the good performance of locomotives, depend of course greatly on the nature of the water used in them. The Firefly and Skipwith engines used in constructing the London and Birmingham railroad, had a coating formed round their tubes nearly half an inch thick, and in consequence they were so nearly burnt through, that several broke by the force of the steam thrusting out each end of the boiler; they were not more than one-sixteenth of an inch thick where they broke, and were found with openings all round them, nearly one-fourth of an inch in width; the water being solely prevented from getting into them by the coating round the outside. Rain water is the best of all where it can be procured, but this will not often be got in sufficient quantity; when stream water is used, it must not be taken from those which run over a lias district, and with either springs or streams passing over or through calcareous matter of any kind, the water should be tested before admitting it in an engine, particularly if the streams run slowly. Throughout the new red sandstone the

water is generally good; a deposit is formed from it, but not a hard one. The safest plan in every instance will be to have at all the places of constant supply, a proper analysis of the water made by a practical chemist, before it is applied to use.

The improvements which had been made in the Planet were very conspicuous. They were, in fact, the combination in one engine of what had previously been known; viz. the blast pipe, the tubular boiler, the horizontal cylinders inside the smoke-box, and the cranked axle, together with a fire-box firmly fixed to the boiler. The Rocket's fire-box was only screwed against the boiler, allowing a great leakage of air which had not passed through the fire. The Planet was in the Mersey, but not landed, when the Liverpool and Manchester line opened. On December 4, 1830, she took the first load of merchandise from Liverpool to Manchester, consisting of 18 waggons containing 133 bags and bales of American cotton, 200 barrels of flour, 63 sacks of oatmeal, and 34 sacks of malt, weighing in the whole 51 tons 11 cwts.; and this with 23 tons 9 cwt., which was the weight of the waggon, 4 tons in tender, water, and fuel, together with fifteen passengers, making a total of 80 tons, exclusive of the engine, was carried the whole distance in two hours 39 minutes, under the disadvantages of an adverse wind and new machinery, where there was of course much additional friction. An additional engine assisted the train up the incline at Rainhill.

Her maximum velocity on a level with the above load was 15½ miles an hour. On the 23d of November 1830, she was engaged to bring up some voters from Manchester to Liverpool for the election, and her setting out having been delayed so long as to render it necessary to use extraordinary despatch, in order to bring them to the poll in time, she performed the journey between the two places in sixty minutes, including a stoppage of two minutes, the usual time allowed for taking in water on the road.

Among the leading improvers of these machines, is Mr. Edward Bury of Liverpool, who now contracts for the locomotive power on the London and Birmingham railway. The distinguishing features of his plan are horizontal cylinders: these were first put outside under the framing, but are now inclosed within the smoke-box, which all his engines have, except two made for the Liverpool and Manchester railway. Inside bearings, and cranked axles, and horizontal cylinders, however, were before used by Gurney in his common road engines. Ericson's engine, the Novelty, also had the former. The first engine made by Mr. Bury was the Dreadnought, which was started on the Liverpool and Manchester railway, March 12, 1830. She had six wheels, and was much objected to on that account. The next was the Liverpool; this was the original engine made by him with horizontal cylinders and cranked axles. She was placed on the Liverpool and Manchester railway, on July 22, 1830, and had an 18-inch stroke, two pair of six-feet coupled wheels, and 12-inch cylinders.

The great danger in cranked axles is from their breaking, which, with four-wheeled engines, might occasion considerable damage. They have been broken repeatedly, but this has not happened fairly to one of Mr. Bury's manufacture; only two have been broken, and, in both cases, from bad welding. One of these, the engine No. 14 on the London and Birmingham railway, was discovered to have been actually running for some time with a broken axle, without its being found out: this arises from the eccentrics being keyed on to the weakest part of the axle, and thus forming a protection against accidents. The above axle had only two-thirds of its section soundly welded when sent from the manufactory.

Mr. Bury's engines are now all made with cranked axles and four wheels, the goods' engines being coupled, and the passengers' not. We attribute the success of his axles in some measure to the mode of constructing the framing, and

to his bearings being inside the wheels, as any shock from obstructions on the road is thus thrown upon the bearings and not on the crank; the framing is made with great breadth, and but little depth, in order to resist lateral shocks; whereas most other makers have great depth, and but little width, which would afford the most powerful resistance to vertical shocks, but, in conjunction with the bearings being outside the wheels, would throw all the lateral ones on the cranks. Many broken axles, however, have been produced by gross neglect in their manufacture. We have seen one which had been welded together, and there was not a junction of a tenth of an inch in the iron, all round; the whole central part being perfectly black, with not the smallest sign of welding. Mr. Bury cuts his out of the solid iron, and only welds the part joining the cranks to set them at right angles. Some makers twist the axles for this purpose.

The first eight engines made by Mr. Stephenson on the Liverpool and Manchester railway, viz. the Rocket, Meteor, Comet, Arrow, Dart, Phœnix, North Star, and Northumbrian, had the cylinders outside the boiler, and worked by a crank pin on the wheel. Mr. Bury's engine, the Liverpool, was then constructed for that railway, and about four months after it had been placed upon the line, Mr. Stephenson adopted the crank axle, and placed the cylinders horizontally, with the improvement of putting them inside the smoke-box. This was done first to his engine, the Planet, and it was suggested by a conversation which Mr. Stephenson had with Trevithick, when they were on their passage from South America. Trevithick stated there was 40 per cent. increase in the duty of Watt's engines (worked expansively) in Cornwall, from putting a jacket on the cylinders. Mr. Stephenson's engines, however, still have their bearings outside the wheels, of which there are three pair. Mr. Bury's and Mr. Stephenson's engines contain, in principle, all that is at present effected by any English makers, although many of them have various modifications in the different details. The

principal remaining difference between them, besides what we have above described, is, that Mr. Bury uses round fire-boxes, and Mr. Stephenson square ones. All other circumstances being equal, the former must evidently be the stronger. Of those minor improvements which have been proposed by various parties, and which appear to be deserving of more or less attention, we shall now give a short account, up to the 1st of January 1839.

Metallic pistons were first applied to locomotives by Messrs. Murdoch and Aiken of Glasgow, in an engine made by them for the Monkland and Kirkintilloch railway, which was set to work in May 1831. There can be no doubt of the economy and great utility of these pistons; and their superiority over the old method of packing, has been so fully established, that they are at present in general use.

In March 1831, Mr. Robert Stephenson took out a patent for an improvement in the axles. It having been found necessary that the wheels should be fixed to the axles, and the weight of the carriage being supported by concave bearings resting on the upper surfaces of the ends of the axles, a difficulty was found in keeping the working parts constantly yet economically lubricated; the oil supplied to these parts at the points of contact having a constant tendency to escape by its gravity to the more open space at the lower part of the axle, thus producing a considerable and continual waste of oil, and at the same time affording a very imperfect lubrication. To remedy this, Mr. Stephenson employed a double axle, consisting of a hollow casing, on the extremity of which the wheel was firmly fixed; through this hollow casing, a solid axle passed, and supported on its ends the weight of the carriage by means of concave bearings connected with springs to the side rails of the carriage, which, for this purpose, was placed on the outside of the wheels. The effect of this arrangement was, that the oil or other unguent used had a constant tendency to accumulate at the precise points at which it was required, namely, on the rubbing parts.

In 1832, Mr. Crawshay, the proprietor of extensive iron works at Cyfaithfa, spoke very favourably of the performance of a locomotive built by Mr. Gurney, principally with a view to travelling on the ordinary roads, but which was fitted to a railroad at Hirwain ; especially as to the ease and economy of first construction, the facility of repairs when required, the extreme lightness, great capability of raising steam, and perfect freedom from danger in the tubular boiler. From January 1, 1831, to January 1, 1832, this engine, which only weighed 35 cwt., including every thing of all kinds belonging to it, with water and fuel in a working state, drew 42,300 tons nett of coal, iron-stone, iron, &c. $2\frac{1}{4}$ miles in journies of 20 to 30 tons, consuming during the entire performance of this work 299 tons of coal, value L.47, 17s.; wages of the engine-man, L.52; wages of the fire-boy L.15, 12s. The other expenses are not given, but Mr. Crawshay stated that the engine would have drawn twice as much if it had been fully employed.

In 1833 a simple mode of registering the speed of any carriage was proposed, which would also shew at what rate an engine had been travelling through every part of its journey. It consisted of a rod turned round by a connection with the engine shaft, and on the rod a small steam-engine governor was fixed, the balls of which opening in proportion to the speed, rose and sunk a point carrying a pencil, and this marked a card which was slowly turned round by a train of wheel work. A curved line was thus traced on the card; consecutive circles gave the various rates of speed ; the engine-man could always see in a moment at what velocity he was travelling; and the rate during the whole journey could be inspected by any person at its end, and any irregularity detected at once.

In January 1833, Mr. Hancock patented a contrivance for remedying the inconvenience experienced by the formation and adhesion of clinkers on the fire bars, by which the combustion of the fuel is checked, and, consequently, the

production of steam, by which the velocity of the engine is considerably lessened. The usual method is by means of a rake to clear away the obstructions from time to time as they arise; and this is found to be quite sufficient, provided the fireman pays proper attention to his duty. Instead of this, Mr. Hancock proposed to draw out the whole floor of bars, and substitute a clean one. For this purpose the bars should be formed in one entire casting, the outer one on each side being cast with teeth under it so as to form a rack: a rail under each of these bars in the fire-box supported the whole floor, and by means of two pinions working into these racks, and turned by a winch, the floor of bars could be withdrawn, and another substituted, by hooking it on to the last end of the set which were to be drawn out.

In July 1833, Colonel Maceroni and Mr. Squire patented a tubular boiler composed of 81 upright cylindric tubes, disposed in nine rows, in the middle of which was the fire-place. The tubes were all connected by horizontal tubes at the bottom and top, the lower being a water communication, and the upper a steam communication. To prevent clinkers and preserve the fire-bars from being rapidly burnt out, they were formed of hollow tubes, through which water circulated to the upright tubes of the boiler.

In October 1833, Mr. Robert Stephenson took out another patent for improvement in locomotives, one object of which was to obviate, as much as possible, the danger of cranked axles. These, with the four-wheeled engines, were found at that time to become strained, and sometimes broken, owing, as was supposed, to the great friction between the flanges of the driving pair of wheels and the rails, especially in going round curves or running into sidings, where the centrifugal force would be called into action and occasion the flanges to bend considerably. It is evident that any bending of the crank axle, although far short of fracture, would occasion such a violent lurching motion, through the wheels being put out of square, that in all probability either

the axle must be broken, or the engine be thrown off the rails. To obviate these disadvantages Mr. Stephenson made his driving wheels without flanges, and added a third pair of small wheels to his engines, in which manner they are now made; the two pair of small wheels having flanges, and the middle, which is the driving pair, having none. The axles of the small wheels being straight, and consequently stronger than the cranked axles, have been found by experience not to be at all liable to bend; and the driving wheels, together with the crank axle, being thus liberated from all lateral strains, the whole of which are transferred to the two pair of small wheels, where there is amply sufficient strength to bear them, have been found to stand their work in a satisfactory manner.

The additional pair of wheels also affording the means of adding to the weight, boilers of greater strength and magnitude were now applied to his engines by Mr. Stephenson, which would occasion them to last much longer, for of course the longer the entire capacity of the boiler is, the more metallic heating surface it will contain, and consequently render, in a great measure unnecessary that intense heat which is so prejudicial to the metal, and which was found to burn out the old boilers very soon. This diminution in the intensity of the combustion had also advantages in another point of view. The jet of waste steam which is thrown into the chimney to produce a rapid draught for exciting the combustion of the fuel, may be diminished in its velocity, and still produce a sufficient effect. This will permit the waste steam from the cylinders to escape with greater freedom than could be permitted with smaller boilers, where a greater heat, and a more rapid generation of steam are indispensable to furnish the requisite power.

Three pair of bearing springs were attached to the engine, one over each pair of wheels, causing all the six wheels to bear equally and fairly on the rails, and to ease all jolts and concussions. These springs were for this purpose spe-

cifically adapted to the respective weight to be borne by each pair of wheels; the main ones, which are impelled by the power of the engine, being in all cases loaded with as much of the total weight as will ensure sufficient adhesion to the rails, so as to prevent any slipping.

In this same patent Mr. Stephenson proposed a new mode of stopping the engine by means of brakes, acted upon by plungers in small cylinders, into which the steam could be let in an instant by turning a small cock. The motion of these pistons was communicated to a system of levers which drew the brakes with considerable force against the periphery of the wheels; by turning the handle of the cock in the opposite direction, the steam was allowed to escape from these cylinders into the open air, and the brakes then separated from the wheels.

In October 1834, Mr. Hick took out a patent for an engine having three cylinders and a three-throw crank: the steam being admitted only at the top of each cylinder, and always forcing the pistons downward, only the bottom of the cylinders being open, when the pistons were ascending, the steam was allowed to escape into the eduction pipe which led into the chimney. The intention of the patentee was to secure, as he supposed, more adhesion between the wheels and the rail, from the power being communicated in a downward direction only; he also anticipated less vibration than when the action of the piston was applied either upwards and downwards, or backwards and forwards. The wheels of this engine were to be formed of a cast iron nave, properly turned and truly bored. This was fitted to receive on each side discs of plate iron instead of spokes; on these discs the external rings and tires were fastened by first expanding their circumference by heat, and then allowing them to contract so as to receive the edges of the discs in grooves, which were turned to receive them; the whole were then screwed together by bolts and keys in the usual manner.

In November 1834, Mr. Whitesides of Ayr, in Scotland, took out a patent for an engine in which the axles were to be firmly fixed to the engine, and the springs were placed inside the wheels, the spokes not reaching the nave, but ending at a ring about eight inches diameter, within which the nave played on helical springs fixed to the inner circumference of the wheel at one end, and to the outer circumference of the nave at the other.

In 1835, Mr. Baldwin of Philadelphia made several very ingenious attempts at improving the locomotives which were constructing by him for several railroads in America. In the first place, the guides of the piston-rods were made hollow, and these cavities used as chambers for the force pump, thus giving additional strength for the guides with but little increase in their weight, and dispensing entirely with the frame and fixtures of the ordinary force pumps. Secondly, his pumps have five valves, the one nearest the boiler being loosely swivelled to a stem passing through a steam-tight collar in the top of the valve box, by means of which the valve can be sounded, and in most cases freed from obstructions: the other four are contained in one box, secured to the pump by a stirrup, which can be removed by loosening a single screw, so that the valves can be taken out, cleaned, and replaced in a few minutes, thus almost insuring a certain and efficient supply of water to the engine. Thirdly, the arms of the rock-shafts extend on opposite sides of the fulcrum, and each eccentric rod has two hooks turned in opposite directions, so that it may be geared to either arm of the rock-shaft, the eccentrics being fixed to the axle. When the eccentric rods are geared to the same arms of the valve rods, the motion of the valves corresponds with that of the eccentrics; but if they are geared to opposite arms, the engine is reversed, and if not geared to either arm, the valves can be worked by the hand-gear. This method dispenses with much complicated machinery. Mr. Baldwin also dispenses with one arm of each crank, fix-

ing the wheel to the wrist of the cranks, which, by this means, are farther apart, admitting of a larger boiler, with a better distribution of its weight. The heels and spokes of his wheels are cast iron, the felloes are of hard wood, on which is a wrought iron tire. This arrangment is found to be advantageously elastic. The steam-pipe is introduced into the boiler through the opening by which it usually communicates between the dome and the cylinders, the throttle-valve being fixed on the steam-pipe. This arrangement allows the pipes to be made without a joint inside the boiler, and no man-hole is required ; the juncture between the dome and the boiler being fitted so as to allow the dome to be readily taken on and off, and its aperture used as a man-hole.

Mr. Bergin's buffing apparatus, which we have before described, was patented in March ; Mr. Booth's axle grease in April 1835. In December Mr. Blythe took out a patent for a method of retarding the speed of railway trains. It consisted of a friction wheel on the inner side of the nave of the carriage wheel. Around this was brought a band, from whence it was conducted and made fast to the carriage body, in such a manner, that in descending an inclined plane, when the carriage body naturally inclines forwards, it drew, by means of the band, the friction wheel against the running wheel, thus creating a retarding force in proportion to the inclination of the plane.

In January 1836, Mr. Booth's draw-bar, which we have before described, was patented ; and at the same time a new method of stopping trains was proposed by the same gentleman, and included in the above patent. This contrivance was to effect its purpose by checking or stopping the speed of the engine, through the means of a throttle-valve introduced into the blast-pipe, just where the two exhausting pipes unite into one, and below the place where the pipe is contracted in area, for the purpose of producing the blast. From this throttle-valve a rod passes through the chimney, and is placed within reach of the engine-man. By

closing this valve, without shutting off the steam, the pistons are speedily, but not suddenly checked, and the engine is soon brought to a stand, without much violence to the machinery.

Early in the same year, a committee of the city council of Baltimore was appointed to witness the performance of a locomotive, built by Messrs. Gillingham and Winans, for the Baltimore and Ohio Railroad Company, by contract, for 50,000 dollars. The weight of the engine was $8\frac{1}{2}$ tons, and the load attached to it was $17\frac{1}{4}$ tons, including the tender, viz.

	Tons	cwt.	qrs.	lbs.
Four-wheeled passenger car, Paterson,....	1	10	2	0
Ditto Patapsco,....	1	15	2	0
Ditto Carroll,......	1	15	2	0
Eight-wheeled double passenger car,.......	4	17	0	0
45 passengers,..................................	3	0	0	0
Tender,..	4	7	0	0
	17	5	0	0

The four-wheeled cars were capable of carrying 17 passengers each, and the eight-wheeled one 44. With the above load the committee state that the performance of the engine on the Baltimore and Ohio Railroad was as follows. A plane 2150 feet long, and rising 197 feet per mile, or 1 in 27, for 2050 feet, and 201 feet per mile, or 1 in 26 for 100 feet, was ascended; the impetus previously acquired on the level being lost in the first 300 feet of the ascent, and the engine then steadily progressing to the top at the rate of four to five miles an hour. A plane 3000 feet long, 2800 of which was at the rate of 170 feet per mile, or 1 in 31; 100 feet at 227 feet per mile, or 1 in $23\frac{1}{4}$; and the 100 feet next the summit at 264 feet per mile, or 1 in 20, was ascended at the rate of 5 to 6 miles an hour, to within 30 feet of the top, when it stopped. The three small cars, weighing 5 tons 1 cwt., were then cast off, and the engine started without assistance, and drew the 12 tons 4 cwt. to the top.

The engine was coupled, and had 12½-inch cylinders with a 22-inch stroke. The boiler contained 400 tubes, and is stated to have furnished an ample supply of steam, but the maximum velocity is not given.

In September 1836 a patent was taken out by Messrs. Van Wart and Goddard, for a locomotive engine, invented by Dr. Church, who had long been labouring to effect steam transit on common roads. The railway locomotive constructed by Dr. Church has a very handsome appearance. It carries its own fuel and water, and the engine-man is placed in the front, not behind, as in the usual arrangement. The frame-work and external casing is of sheet iron, the water tank being low down, and outside the wheels. The furnace is nearly surrounded with water communicating with the boiler, and its flues terminate in a series of vertical tubes, which lead to the chimney, and which are also surrounded by the water in the boiler. The cylinders are horizontal, and placed in the fore part of the engine, and there are safety valves to each of the two steam chambers. The wheels are very similar to those of Mr. Hick's, being formed with slender spokes made of thin bar iron, fixed at their inner ends into the nave, by having the ends of the metal upset in the shape of a dovetail. These are made fast in the nave by caulking; their outer ends butt against the inside of the rim of the wheel. These spokes have their breadth at right angles to the plane of the wheel, and are boxed in on each side by a circular plate or disc of sheet iron, confined in its situation partly by a series of tenons formed on the edges of the spokes, which pass through corresponding mortices in the discs, and are then rivetted on the outside. Both the discs are attached to the nave of the wheel, by having their inner edges upset in the form of a dovetail. They are then heated and secured, by rivetting over, into slight grooves, against dovetailed shoulders formed round the nave. In the same manner the outer edges

of the discs being also upset in the form of dovetails, are inserted into grooves inside the rim of the wheel, by heating the rim, and then shrinking it on to the discs, after which the rim is caulked upon the dovetailed edges, so as to secure the discs firmly.

In December, Mr. Harrison took out a patent for an engine, having cogged wheels, with a view to diminishing the velocity of the piston, the driving wheels of the engine making three revolutions for each complete stroke of the piston; and as they are five feet in diameter, they would give a velocity equivalent to fifteen-feet wheels, with the same number of strokes per minute. The boiler is placed on one carriage, and the cylinders and machinery on another, each having four wheels. The cylinders are horizontal, and the connecting rods are attached to a double cranked axle, on which is the cogged wheel; this works a pinion on the axle of the driving wheels. The axle of the driving wheels has a motion up and down, as usual, to allow for imperfections in the road; and the cogged wheel and pinion are kept at the requisite distance in gear, by the supports of the cranked axle being fixed over and connected with those of the driving wheels, and thus moving in conjunction with them. Two eccentrics on the cogged wheel-axle work the slides with the usual levers and hand-gear, and the steam from the cylinders is thrown into the chimney. The two carriages are connected by a bar, and the steam pipes have a ball and socket joint for lateral motion, with a metallic ring packing; they also are composed of two parts, which slide one within the other, allowing by this means a motion in the direction of their length. The tank is under the boiler, and the engine wheels are coupled, in order to have the whole weight, for the purpose of obtaining adhesion. In order to keep the teeth at the right pitch, and prevent backlash, on reversing the motion, the pinion is in two parts, one of which is moveable round

the axle, and by means of keys these may be set, so as to place the two halves of the teeth a little out of the right line, and thus tighten their action.

In April 1837, Mr. Henry Booth took out a patent for supplying the fuel to locomotive (or stationary) engines, by means of a coal-box attached behind the fire door of the usual furnace, from which the fuel is proposed to be introduced into the furnace, through a long narrow aperture, extending the whole width of the furnace, instead of its being supplied, as now usually done, through the fire door. The door to the coal-box, which is twice the size of the furnace door, being opened, and also the furnace door, the furnace is charged with coal, and lighted in the ordinary way; the furnace door being then shut, the coal-box is also charged with the fuel, which lays on fire-bars, forming an inclined plane; on this the coal descends gradually into the furnace. The coal-box is kept constantly filled up a few inches above the bottom of the water space, or outer casing, under the fire door, along the whole width of the furnace. When the fuel is properly ignited in the furnace, if the engine is in motion, the shaking of the boiler, furnace, and coal-box, assisted by the inclined position in which the coal lies on the plane, will partially supply the furnace with fresh fuel: any further desirable quantity may be introduced by using a pushing rake between the bars of the inclined plane from below, through the narrow slits made for that purpose in the coal plate; and this fresh coal goes under that which is already ignited, by which means its smoke is in a great measure consumed, at a consequent saving in the consumption of fuel.

During the same month, a patent was taken out by Sir George Cayley for a locomotive engine for either common roads or railways, to be worked by hot air, partially assisted by a small portion of steam, at first starting, or at any difficult points, which steam is to be produced by the injection of water through a rose-ended pipe into the furnace.

In May, Mr. Hague took out a patent for carriage wheels. These appear to be exactly similar to those of Mr. Losh's, with the latest improvements, except that Mr. Hague, after he has bent his iron round so as to form two half spokes and a connecting felloe, (which connecting felloe, when the requisite number are put together, forms the inner rim of the wheel), welds the ends together before casting the nave round them.

In June, Mr. Thomas took out a patent for a mode of economizing fuel, by conducting the waste steam from the engine through the fire bars, which are made hollow, and allowing it to enter among the fuel, through jets, where the vapour becoming decomposed, and forming new combinations with the gases arising from the burning fuel, ignition takes place. We are not aware what is the success of this invention ; but a jet of steam thrown into pit coal smoke, in a slanting direction, from above the fire, has been successfully used, both in a great measure to effect the consumption of the smoke, and to produce also a reduction in the quantity of fuel.

On the 21st of the same month, Mr. Harrison obtained a patent for placing locomotives on two carriages instead of one, the boiler and engine being separated, so as each is mounted on its own carriage, and a connexion formed by ball and socket joints, to convey the steam to the cylinders, by which means only the one which required any repairs would be laid up, and the remaining part could be attached to another boiler or engine, as the case might be, so as to lessen considerably the expense of keeping a large number of spare engines, as well as that of sometimes nearly stripping an engine to repair perhaps a part of the boiler.

An American engine, made by Morris of Philadelphia is now on trial for the Gloucester and Birmingham Railway, and is spoken very highly of. It has one pair of driving wheels, and two pair of running ones, very small, and turning with their frame on a pivot, to assist in going round

curves. Its performance up inclines, in particular, is spoken very highly of; being 120 tons at 18 miles an hour up the Whiston plane on the Liverpool and Manchester Railway. It has been got up almost without the use of a file by lathes and planing machines. The pistons and working parts are all outside the framing, which allows the boiler to be very low down. The driving wheels are 4 feet diameter, and the running ones 2 feet 6 inches. It has 76 tubes, and works by a crank-pin outside; the wheel 9 inches from the centre of the axle.

Mr. Melling of Liverpool is the inventor of a new motion for opening and shutting the slide valves; but as it requires a drawing to explain it, we must refer to a very good one in the railway Glossary, published by Williams, Great Russell Street, London; and we shall close this description of the various attempts at improving the construction of locomotives, by a statement of the proper proportion of tubing for the boilers, so as to afford in the aggregate a maximum quantity of surface exposed to the hot air. Mr. Buck, at the. Civil Engineers' Institution, January 1839, gives this as follows; namely, that the distance between the diameter of each adjacent tube should be four times the interval between their internal surfaces, by which means from 23 to 26 per cent is gained in evaporating power beyond the general method.

Fig. 1 and 2.—Plan of a mode of working inclined planes with ropes and sheeves. Fig. 1 is the horizontal wheel at one end of the lines of rails, and fig. 2 is the working-wheel, with its pit and tightening-sheeves; this wheel is worked by a fixed engine. This plan was adopted on the Liverpool and Manchester Railway by Mr. Stephenson.

Fig. 1.

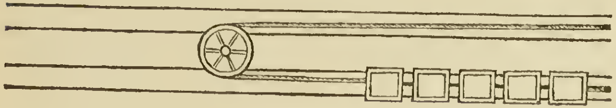


Fig. 2.

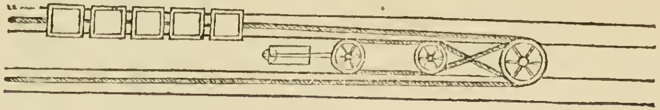


Fig. 3.—Plan of passing places or crossings from one line to the other, which may be used when trains travel at two velocities, to enable them to get by each other.

Fig. 3.

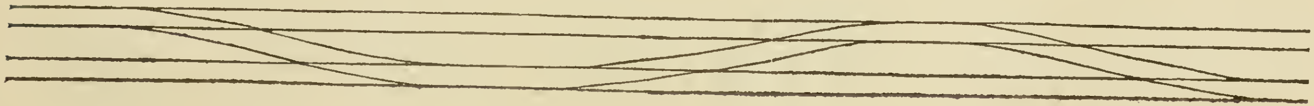


Fig. 4.—A transverse section of Mr. Stephenson's method of crossing Chatmoss.

Fig. 4.

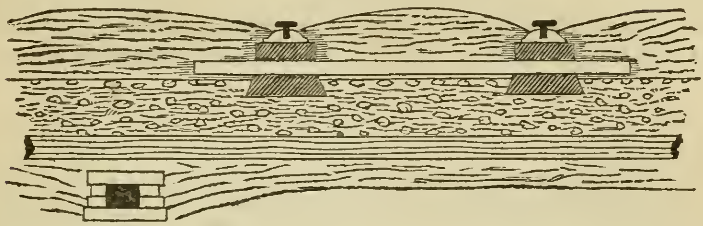
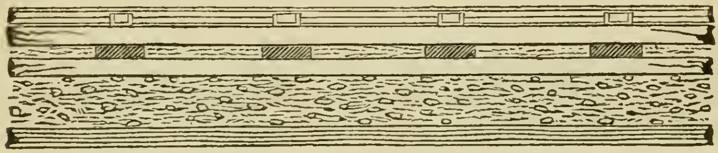


Fig. 5.—Longitudinal section of the same. At the bottom are the hurdles and the main drain, (fig. 4), then comes the ballasting, and on that the longitudinal sleepers, then the transverse ones; on these another set of longitudinal ones are laid, which last receive the two rails and chairs.

Fig. 5.



Figs. 6 and 7 shew passing places on railways having only one line of rails. In fig. 6, one side is taken by the carriages going in one direction, and the other by those going the contrary way. In fig. 7, *a*, *a* is the passing place into which the carriages go to admit another train going by them on the main line.

Fig. 6.

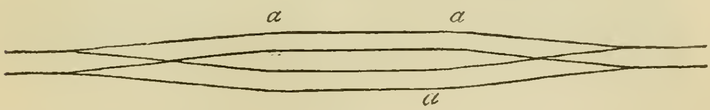


Fig. 7.

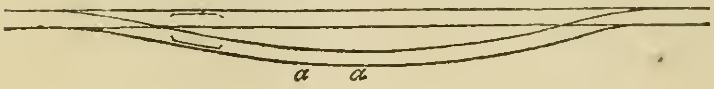


Fig. 8.—Longitudinal section of the Great Western, (see p. 240.) At every 15 feet in length along the railway, beech piles are driven into the ground at 15 feet distance apart transversely; they are driven from 8 to 10 feet in cuttings; and in embankments they are generally sufficiently long to reach the ground on which the embankment rests.

Fig. 8.

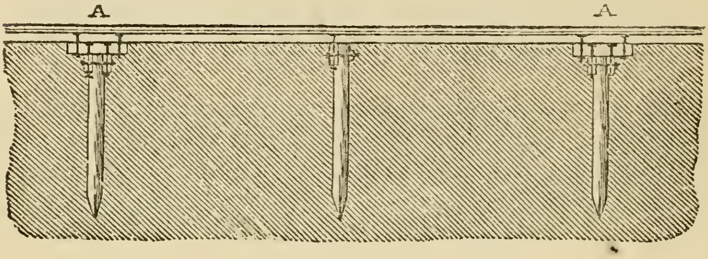
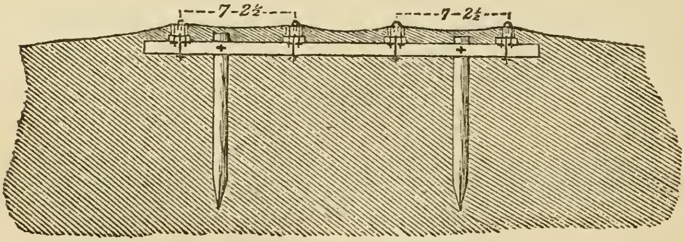


Fig. 9.—Transverse section. The piles are formed to the proper length, and driven in without any being cut off their heads, which are nearly level with the top of the ballasting; they do not stand in the middle of each line of rails, but are nearer each outside of the two lines.

Fig. 9.



To these piles double and single transverse ties or sleepers are attached. A square shoulder is cut 1½ inches into the pile on one side for the single ties, and on both sides for the double ones; the single ties are 6 inches broad, and 9 inches deep; the double ties are 6 inches broad, and 7 inches deep.

Fig. 10.—Plan. The guage of the Great Western Railway is 7 feet 2½ inches from centre to centre of the rails, and the width between the two lines is 6 feet.

Fig. 10.

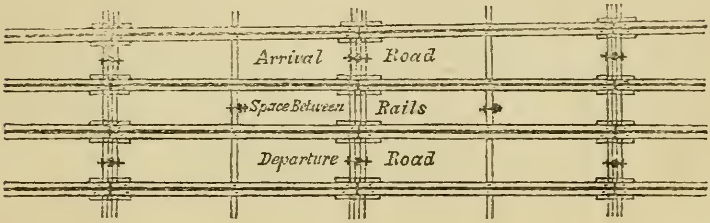
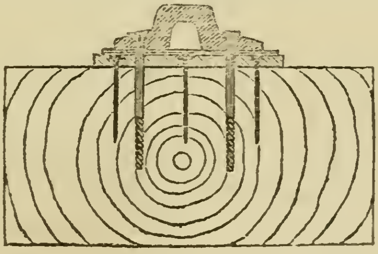


Fig. 11.—Enlarged view of the rail. The rails are screwed down to the plank and longitudinal bearer, with felt underneath them. The whole of the timber is kyanised, and the joints, butts, bolts, &c. are tarred. In fixing the rails, square-headed screws are used outside the rails, and countersunk ones inside, to be clear of the flange of the wheels.

Fig. 11.



EXPLANATION OF THE PLATES.

Plate CCCCXX. fig. 1, is a plan of a sliding rail and eccentric for a crossing or siding place. The eccentric being attached by rods to the sliding rails (which move on a joint at the opposite end) draws them to either line, as required.

Fig. 2 is a longitudinal, and fig. 3 a transverse section of the same.

Fig. 4 shews a plan and section of a fixed point.

Fig. 5 shews the general arrangement of the whole of the preceding figures, to form a complete crossing.

Fig. 6 is a plan, fig. 7 a longitudinal, and fig. 8 a transverse section of the mode of laying the blocks, sleepers, and rails in an excavation, together with the ballasting, and an approved method of drainage. The blocks are shewn as laid diagonally in the manner they have been on the London and Birmingham Railway. The drains are of brick.

Plate CCCCXXI. fig. 1, is a mail carriage, as at present used, with its imperial.

Fig. 2 a side, and fig. 3 an end view of a first-class carriage.

Plate CCCCXXII. fig. 1, shews a close second-class carriage, with brakes which are worked by the handle at the top of the right hand end.

Fig. 2 is a plan of the buffer and drawing apparatus for the first and second-class carriages, and the mails.

Fig. 3 is a third-class carriage, and fig. 4 a plan of the drawing apparatus. In these carriages there are no buffer springs, but merely blocks at each end of the body. On some railways, the second-class carriages shewn here are not used, but the third-class, with the addition of a roof, is called the second-class. When this is the case, the ends are generally closed, but he sides are left open.

Fig. 5 shews a different form of buffing apparatus used on the Dublin and Kingston Railway; the buffer rod goes the whole length of the carriage, having a similar head and the spring at other end.

Plate CCCCXXIII. figs. 1 and 2, are an end and side view of an approved earth waggon; and figs. 3 and 4 shew another which has been very generally adopted. The brakes are shewn in both.

Plate CCCCXXIV. fig. 1, is a ground plan of the London and Birmingham Railway engine-house at Birmingham, shewing also the mode of laying on the water; *a, a, a* are the main water pipes; *b, b, b* air vessels placed over the main pipes, to prevent the ram of the water when the cleansing and forcing cocks are shut suddenly, which, with a considerable head of water, would endanger breaking the pipes; *c, c, c* cleansing and forcing cocks; these have strong hoses attached to them, by means of which an engine standing over the cleansing pits *d, d, d,* may be worked, and the boiler cleansed, and also filled when the steam is up, the usual force of water on the jet being 78 lbs. 10 oz. to the square inch; *e, e, e* lines of rails from the central turnplate to each engine pit.

Fig. 2 is a sectional view of the guard pipes through which the water mains are taken, when they cross the lines of rails as seen in fig. 1, in order to prevent damage to the road from leakage or accident. They also admit new pipes being laid down without disturbing the rails; *a* is the iron guard pipe; *b* the water main; *c* man-hole for an entrance to the guard pipe; under this, at the lower part of the man-hole, is a drain to the nearest culvert.

Fig. 3 is a general plan of a siding on each side of the main lines, and also of a crossing from one line to the other. See also Plate CCCCXX. figs. 1 to 5.

Fig. 4 shews the rope as attached to the working wheels in the fixed engine-house at Camden Town, on the London and Birmingham Railway, by which the trains are drawn up from Euston Square. To obviate the effects of the atmosphere on the rope, a tightening wheel, travelling on a railway, as shewn in fig. 5, is used, from which a heavy weight is attached by a chain, and hangs in a well; by this means there is always an equal tension on the rope. The running sheeves on inclined planes should be very well fitted, and nearly all noise will be prevented by covering their working edges with netting.

Plate CCCCXXV. fig. 1, is a vertical section of a water crane; *a* the lever for opening the upper valve inside the tank; *b* the tank; *c* a compartment to be filled and warmed by the exhaust steam from the pumping engine, so as to warm the water before it is filled into

the locomotives; the escape steam from the safety valve also is blown into the compartment *c*; *d*, *d* the ends of the boilers; *e* the supply pipe, fitted with a stuffing gland at the top at *f*, where it enters the tank to allow for expansion; *g* the continuation of the supply pipe, which goes to the crane on the opposite line of rails; the blank flange has a cock at *h*, by which the pipes can be emptied and cleaned, also to prevent the water freezing; *i* the crane turning in a gland at *k*, and a collar at *l*; *m* the brace of the crane; *n* the gib of the crane; *o* hose of the supply valve for filling the engines; *p* a leather hose to conduct the water. When the fall of water is high, these cranes must be very firmly fixed, or else instead of a supply valve on the gib, they must be fitted with a sluice cock fixed in the horizontal portion of the pipe; *s*, *s* the line of rails. When not in use, the cranes are turned round flat against the wall *t*, to which they are fixed.

Fig. 2 is an end view of the part *h*.

Fig. 3, plan of an invalid carriage; *a*, *a* the seats; *b*, *b* doors leading into the passage *d*; *c*, *c* apartments containing portable water-closets; *c′* do. containing a urinal; *d*, *d* passage from each body to the water-closets; *e* door to urinal; *f* and *g* doors to the water-closets.

Fig. 4, plan of a smoking carriage, having seats (*c*), in the direction of its length, and a place (*a*), fitted with shelves for the attendant to keep cigar boxes, soda water, &c.

Fig. 5 is an elevation of a mile mark; the numbers are either painted on glass, or cut out from sheet iron; the box at the top contains a lamp, which will shew the miles by night.

Plate CCCCXXVI. fig. 1, elevation and section of a water apparatus for washing the carriages, as constructed on the London and Birmingham Railway; *d* air vessels to prevent the ram when the cocks are shut suddenly; *a*, *a* saddle cocks fitted with hollow plugs, one of which is shewn detached at *g*; *c*, *c* hollow space to be filled with charcoal, as a security against the water being frozen; *b* the connection with the feed pipe by means of a union joint; *e* the feed pipe; *f*, *f* holding down pins.

Fig. 2, elevation of the west end of the great Blisworth cutting on the London and Birmingham Railway, shewing the method of undersetting the rock.

Fig. 3 is a section of the side walls at the same place; the left hand side shews a section of the wall in the recesses, and the right hand side shews the same through a buttress, together with the invert and drains.

Fig. 4 is an elevation of fig. 3.

Fig. 5 shews the method of drawing bridges to answer both for cuttings and embankments. The left hand side is for a cutting and a bridge over the railway ; the right hand side is for an embankment and a bridge under the railway.

Fig. 6 is a plan of the fixed engine-house at Camden Town, on the London and Birmingham Railway, where the trains are drawn up from Euston Square. There are four lines of rails for a double railway; between these are the stairs leading down to the engine-room, on each side of which are the boiler rooms, with receptacles for fuel, &c. The working wheels for the endless rope are in the engine-room, and the well and tightening sheeve behind it. The mode of working these is shewn on a larger scale in Plate CCCCXXIV. figs. 4 and 5.

Plate CCCCXXVII. fig. 1, plan of a station ; *s*, road to the booking offices ; *d*, building, containing booking offices, waiting rooms, and the offices requisite for the general railway business ; on the opposite side of this building, on the road *s*, is the departure platform, and line of rails which go to the left ; *e*, the first-class carriage house ; *f*, the second-class carriage house ; *g*, the stables for the goods' station ; *h*, the goods' waggon house ; *c*, the gullet for embarking horses and private carriages ; *i*, the engine house ; *p*, coke store, with tank over it ; *m*, store-house for the engine department ; *k*, repairing house and engine manufactory ; *n*, lathe room ; *t*, road next the arrival stage to the town for the passengers inwards ; *b*, offices for goods and general store department ; *q*, *q*, goods' arrival and departure sheds, with roads, *t* and *s*, to and from the town ; *a*, the point from which the engine tows in the goods' arrival trains with a rope ; *r*, workshops, lodging houses, &c.

Fig. 4, another plan of a principal station in which turnplates are required ; the same letters refer to the same things.

Fig. 2, an elevation, and fig. 3 a plan of the fittings to a booking office ; *a*, *a*, the counter ; *b*, the clerks for booking second-class passengers ; *c*, the clerks for booking first-class passengers. The first-class passengers enter by the right hand door c', and having received their tickets, pass through c'' to the door c''', which leads to the first-class waiting room and the platform. The second class passengers enter by the left hand door b', and in like manner pass through b'' and b''' which leads to the second-class waiting room and platform.

Plate CCCCXXVIII. *Turnplates in plan and section, with details.*

Fig. 1, the plan ; fig. 2, the section ; fig. 3, elevation of the frame ;

fig. 4, catches; these should have long handles to lift them by; fig. 5, elevation of roller and turnplate on it; fig. 6, the roller; fig. 7, section of the roller; fig. 8, provision to lock the plate when required, by inserting a bolt through the plate and frame.

Plate CCCCXXIX. *a*, the steam whistle which is made use of to warn workmen on the road, and persons on the stations, when the engine is approaching; *b*, an elevated dome, up which the steam pipe rises to nearly the top, to prevent the motion of the engine throwing water out of the boiler. This dome, when taken off, forms the man-hole; *c*, working safety valve, the lever of which is attached to a spring weighing-machine; *d*, lock-up safety valve, which is screwed down to the required pressure by a series of springs; *e*, chimney; this generally has a wire gauze at the top to prevent the escape of sparks, and sometimes a damper to regulate the force of the blast-pipe; *f*, smoke box, in which are the cylinders, the end of one of which is seen at *g*, with the cock *h*, which is to let out condensed water or priming from the cylinder. There is a large door in the front of the engine, opening into the smoke-box, to allow of repairs being made to the cylinders, tubes, &c. inside; *i*, *i*, *i*, three guage cocks, to ascertain the height of the water in the boiler; *k*, water guage, shewing in a glass tube the height of the water in the boiler. This guage communicates by a cock at the top with the steam, and by one at the bottom with the water. It also has a second cock at the bottom, for the purpose of emptying it when necessary; *l*, steam regulator, by turning which, the steam is shut off, or let into the cylinders; *m*, railing round the place where the engine-man and fireman stand; *n*, fire box, containing the furnace, round which a thickness of about three inches of water circulates from the boiler; the top is also full of water to the height of that in the boiler; *o*, supply pipe connected with the tender, from which water is pumped in at pleasure by means of the pumps *p*, which are worked by arms fixed on the piston rods, and running in guides; *q*, the handle which turns the pet cock; this is used by the engine-man to ascertain when his pumps are in proper order, in which case it throws out water, but when they are deranged it gives out steam; there is one on each side of the engine; *r*, cock by which the boiler is emptied, and the engine blown off. Plates also take off at the bottom of the boiler, and open into the mud-holes, which are also used to clean the engine internally; *s*, *s*, strengthening rods to the frame-work of the engine; *t*, *t*, stays from the framing to the boiler; *u*, draw-bar to which the tender is attached; *v*, door to the furnace; there is a similar one to the lower

part of the fire-box, which is formed into the ash pit, and is open to the front for the purpose of increasing the draft; *w*, the frame-work of the engine. Some makers place this with its breadth horizontal instead of vertical, and Mr. Bury of Liverpool has his bearings inside the wheels instead of outside; *x*, *x*, the axle guards which play up and down in grooves in the sides of the axle-boxes; *y*, hook for attaching carriages to the foremost end of the engine; there is a similar one on the other side; *z*, the buffer.

The lower part of the boiler has a number of brass tubes running along its whole length, through which the flame and hot air rush in their passage to the chimney, up which the steam, after it has performed its office in the cylinders, is thrown through an iron pipe called the blast pipe. This is one of the most essential of all the improvements of the locomotive. The boiler is cased with wood, to preserve the heat as much as possible; its tubes last about two years, and cost about L.1 each.

The steam pipe, by which the steam is conveyed to the cylinders, is divided into two after it enters the smoke-box, and one goes to each cylinder; these are all made of copper, and the entrance and exit of the steam into the cylinder is regulated by slide valves worked by eccentrics on the cranked axle, which move levers fixed to the weigh bars. The pistons are formed of metal rings in several divisions, so placed as to break joint. The piston rod is fixed with a joint to the connecting rod; and this last gives motion to the cranked axle, having its end next the piston rod fixed to the cross heads, each end of which work in guide blocks, thus causing a parallel motion in the piston rod.

The cranks are placed at right angles to each other, to enable the engine to get over her centres; one piston thus works at the greatest advantage, when the other is at the least. By the eccentrics on the crank axle, and a series of levers, the slide valves are continually worked backwards and forwards with the engine, and this motion can be reversed instantly, so as to cause the engine to go in the opposite direction when required; this is done by means of the long handle near the fire box, which moves against an arc having three notches in it; when the handle is placed in the upper or lower notch, the engine goes either forward or backward, and when in the middle, the slide valves no longer work. There are many modes by which this is arrived at by different makers, and there is generally two starting handles, by pulling which the slides can be worked by hand; these are constantly in motion while the engine is going.

Proper cups containing oil are placed over each of the working parts, so as to ensure a steady and constant supply of oil to every moving portion of the engine. These cups have a tube inside them, which leads through to the part which is intended to be supplied with oil, and a cotton wick is put through the tube, one end of which hangs over the top into the oil cup, and thus acts as a syphon. The axle boxes are filled with grease, and have a cover on the top to ensure a proper lubrication of the axles.

Inside bearings are often used to strengthen the engine, and ensure its correct action ; they also steady the cranked axle against the horizontal force of the piston rods. The whistle is formed by a pipe through which the steam is allowed to pass at pleasure, by turning a cock; it then rushes against the thin edge of the upper domed part, which is hollow like a bell, and gives out a clear sound when the cock is properly turned, which may be heard at a very great distance.

The buffers consist of leather cushions stuffed with horse hair, and their use is to break the shock arising from any concussion which the engine may receive. Each of the wheels has a cover, called a splasher, placed over them, to prevent their throwing the dirt from the rails into the machinery. Sometimes two pair of wheels are coupled together ; this gives more adhesion, and is generally done to goods' engines only, which also have usually their wheels of less diameter than those used for passenger trains, velocity being not so much an object as power of draught. Mr. Stephenson does not now make his engines with any flanges on the middle pair of wheels.

A RETURN of all MONIES to be raised under the sanction of the Acts whereby Railroad Companies have been incorporated, between the 1st day of January 1826 and the 1st day of January 1839; distinguishing the Sums to be raised as Principal from the Sums to be raised by Loan or Mortgage; and stating the several Acts under which the said several Sums are to be raised.

(From the First Report of the Select Committee of the House of Commons on Railways.)

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
broath and Forfar	6 Will. 4, c. 34, s. 6. 78	19 May 1836	70,000	35,000	105,000
ron and Gloucestershire	9 Geo. 4, c. 94, s. 40. 45	19 June 1828	21,000	10,000	31,000
	1 & 2 Will. 4, c. 12, s. 8	30 July 1831	...	15,000	15,000
			21,000	25,000	46,000
lesbury -	6 Will. 4, c. 37, s. 3. 172	19 May 1836	50,000	16,000	66,000
llochney -	7 Geo. 4, c. 48, s. 27. 32	5 May 1826	18,431	10,000	28,431
	5 & 6 Will. 4, c. 97, s. 1	21 Aug. 1835	...	10,000	10,000
			18,431	20,000	38,431
lfast and Cavehill -	2 Will. 4, c. 35, s. 54. 63	9 April 1832	7,500	2,500	10,000
	5 & 6 Will. 4, c. 112, s. 24. 27	9 Sept. 1835	26,000	2,700	28,700
			33,500	5,200	38,700
rmingham and Derby Junction - -	6 Will. 4, c. 35, s. 3. 200	19 May 1836	630,000	200,000	830,000
rmingham and Gloucester	6 Will. 4, c. 14, s. 108. 131	22 April 1836	950,000	316,666	1,266,666
rmingham, Bristol, and Thames Junction -	6 Will. 4, c. 79, s. 3. 139	21 June 1836	150,000	50,000	200,000
shop Auckland and Weardale	1 Vic. c. 122, s. 54. 60	15 July 1837	72,000	24,000	96,000
ydon, Gateshead, and Hebburn - -	4 Will. 4, c. 26, s. 53. 61	22 May 1834	60,000	20,000	80,000
dmin and Wadebridge	2 Will. 4, c. 47, s. 62. 69	23 May 1832	22,500	8,000	30,500
	5 & 6 Will. 4, c. 93. s. 2	30 July 1835	...	5,000	5,000
			22,500	13,000	35,500
lton and Leigh -	9 Geo. 4, c. 8, s. 2	26 Mar. 1828	25,000	...	25,000
	1 & 2 Will 4, c. 11, s. 24	30 July 1831	additional 16,500	25,000	41,500
	6 Will. 4, c. 52, s. 8	20 May 1836	additional ...	60,000	60,000
			41,500	85,000	126,500

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
Bolton and Preston -	1 Vic. c. 121, s. 136. 160	15 July 1837	380,000	126,500	506,50
Brandling Junction -	6 Will. 4, c. 57, s. 5. 119	7 June 1836	110,000	36,000	146,00
	1 Vic. c. 22, s. 1 -	11 June 1838	190,000	...	190,00
			300,000	36,000	336,00
Bridgend - -	9 Geo. 4, c. 92, s. 39. 44	19 June 1828	6,000	4,000	10,00
Bristol and Exeter -	6 Will. 4, c. 36, s. 3. 247	19 May 1836	1,500,000	500,000	2,000,00
Bristol and Gloucestershire	9 Geo. 4, c. 93, s. 46. 58	19 June 1828	45,000	12,000	57,00
	4 Will. 4, c. 2. s. 2 -	26 May 1834	20,000	...	20,00
			65,000	12,000	77,00
Canterbury and Whitstable	8 Geo. 4, c. 11, s. 15	2 April 1827	19,000	...	19,00
	9 Geo. 4, c. 29, s. 3 -	9 May 1828	additional 21,000	...	21,00
	5 & 6 Will. 4, c. 82, s. 29	21 July 1835	additional ...	40,000	40,00
			40,000	40,000	80,00
Carmarthenshire -	4 Will. 4, c. 70, s. 2 -	27 June 1834	12,000	6,000	18,00
Cheltenham and Great Western Union -	6 Will. 4, c. 77, s. 3. 153	21 June 1836	additional 750,000	250,000	1,000,00
Chester and Birkenhead	1 Vic. c. 107, s. 96. 118	12 July 1837	250,000	80,333	330,33
Chester and Crewe -	1 Vic. c. 63, s. 101. 123	30 June 1837	250,000	83,333	333,33
Clarence - -	9 Geo. 4, c. 61, s. 34. 38	23 May 1828	100,000	60,000	160,00
	10 Geo. 4, c. 106, s. 17	1 June 1829	100,000	...	100,00
	2 Will. 4, c. 25, s. 2 -	3 April 1832	100,000	...	100,00
	3 Will. 4, c. 4, s. 10 -	29 Mar. 1833	60,000	...	60,00
	3 Will. 4, c. 95, s. 8 -	18 June 1833	20,000	...	20,00
	1 Vic. c. 103, s. 2 -	12 July 1837	60,000	...	60,00
			440,000	60,000	500,00
Coleorton - -	3 Will. 4, c. 71, s. 4. 14	10 June 1833	25,000	6,000	31,00
Commercial - -	6 & 7 Will. 4, c. 123, s. 3. 209	28 July 1836	600,000	200,000	800,00
Cork and Passage -	1 Vic. c. 108, s. 86. 107	12 July 1837	200,000	66,000	266,00
Deptford Pier Junction	6 Will. 4, c. 63, s. 4. 119	21 June 1836	60,000	20,000	80,00
Dublin and Drogheda	6 & 7 Will. 4, c. 132, s. 3. 201	13 Aug. 1836	600,000	200,000	800,00
Dublin and Kingstown	1 & 2 Will. 4, c. 69, s. 66. 75	6 Sept. 1831	200,000	70,000	270,00
Duffryn Llynvie and Porthcawl - -	10 Geo. 4, c. 38	14 May 1829	...	12,000	12,00
Dulais - -	7 Geo. 4, c. 102, s. 45. 80	26 May 1826	... 10,000	additional 4,000	... 14,00
Dundalk Western -	1 Vic. c. 96, s. 70 -	3 July 1837	100,000	...	100,00
Dundee and Arbroath	6 Will. 4, c. 32, s. 50. 58	19 May 1836	100,000	40,000	140,00
Dundee and Newtyle -	7 Geo. 4, c. 101, s. 31. 36	26 May 1826	30,000	10,000	40,00
	11 Geo. 4, c. 60, s. 2. 5	29 May 1830	10,000	20,000	30,00
	6 and 7 Will. 4, c. 102, s. 2	4 July 1835	100,000	...	100,00
			140,000	30,000	170,00
Durham and Sunderland	4 and 5 Will. 4, c. 96, s. 15	13 Aug. 1834	102,000	...	102,00
	1 Vic. c. 67, s. 40, 41	30 June 1837	90,000	64,000	154,00
			192,000	64,000	256,00

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
Durham Junction -	4 Will. 4, c. 57, s. 59. 67.	16 June 1834	80,000	34,000	114,000
	1 Vic. c. 97, s. 9	3 July 1837	12,000	4,000	16,000
			92,000	38,000	130,000
Eastern Counties -	6 & 7 Will. 4, c. 106, s. 3. 246	4 July 1836	1,600,000	533,333	2,133,333
Edinburgh and Dalkeith	7 Geo. 4, c. 98, s. 54	26 May 1826	70,125	...	70,125
	4 and 5 Will. 4, c. 71, s. 9	27 June 1834	8,053	...	8,053
	10 Geo. 4, c. 122, s. 3	4 June 1829	54,875	...	54,875
			133,053	...	133,053
Edinburgh and Glasgow	1 and 2 Vic. c. 58, s. 121. 143	4 July 1838	900,000	300,000	1,200,000
Edinburgh, Leith, and Newhaven - -	6 & 7 Will. 4, c. 131, s. 44. 73	13 Aug. 1836	100,000	40,000	140,000
Exeter and Crediton -	2 Will. 4, c. 93, s. 55. 64	23 June 1832	35,000	12,000	47,000
Festiniog - -	2 Will. 4, c. 48, s. 51. 58	23 May 1832	24,185	10,000	34,185
	1 and 2 Vic. c. 80, s. 2	27 July 1838	12,000	...	12,000
			36,185	10,000	46,185
Forest of Dean -	7 Geo. 4, c. 47, s. 24	5 May 1826	125,000	...	125,000
Garnkirk and Glasgow	7 Geo. 4, c. 103, s. 27	26 May 1826	28,497	...	28,497
	8 Geo. 4, c. 88, s. 8	14 June 1827	9,350	...	9,350
	11 Geo. 4, c. 125, s. 2	7 June 1830	...	21,150	21,150
	1 and 2 Vic. c. 60, s. 1	4 July 1838	89,198	...	89,198
			127,045	21,150	148,195
Glasgow, Paisley, and Greenock - -	1 Vic. c. 116, s. 104. 128	15 July 1837	400,000	133,333	533,333
Glasgow, Paisley, Kilmarnock, and Ayr - -	1 Vic. c. 117, s. 104, 126	15 July 1837	625,000	208,300	833,300
Grand Junction -	3 Will. 4, c. 34, s. 106. 113	6 May 1833	1,040,000	346,000	1,386,000
	4 Will. 4, c. 55, s. 27	16 June 1834	...	520,000	520,000
			1,040,000	866,000	1,906,000
Great Leinster and Munster	1 Vic. c. 104, s. 79. 100	12 July 1837	800,000	265,000	1,065,000
Great North of England	6 & 7 Will. 4, c. 105, s. 3. 198	4 July 1836	1,000,000	150,000	1,150,000
Great North of England Clarence and Hartlepool Junction -	1 Vic. c. 95, s. 51. 72	3 July 1837	52,500	17,500	70,000
Great Western -	5 & 6 Will. 4, c. 107, s. 3. 237	31 Aug. 1835	2,500,000	833,333	3,333,333
Hayle - -	4 Will. 4, c. 68, s. 50, 60	27 June 1834	64,000	16,000	80,000
Heckbridge and Wentbridge	7 Geo. 4, c. 46, s. 57. 66	5 May 1826	11,300	2,800	14,100
	8 Geo. 4, c. 20, s. 6	12 April 1827	7,600	...	7,600
			18,900	2,800	21,700
Hereford -	7 Geo. 4, c. 100, s. 39. 44	26 May 1826	23,000	12,000	35,000
Hull and Selby -	6 Will. 4, c. 80, s. 3. 199	21 June 1836	400,000	133,333	533,333
Kenyon and Leigh -	10 Geo. 4, c. 36, s. 57. 65	14 May 1829	25,000	6,250	31,250
Kilmarnock and Troon	1 Vic. c. 105, s. 2	12 July 1837	40,000	...	40,000
Lancaster and Preston	7 Will. 4, c. 22, s. 102. 124	5 May 1837	additional 250,000	83,000	333,000

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
Leeds and Selby -	11 Geo. 4, c. 59, s. 59, 69.	29 May 1830	210,000	90,000	300,000
	5 Will. 4, c. 57, s. 16	3 July 1835	...	40,000	40,000
			210,000	130,0 0	340,000
Leicester and Swannington	11 Geo. 4, c. 58, s. 4. 14	29 May 1830	90,000	20,000	110,000
	3 Will. 4, c. 69, s. 24. 26	10 June 1833	10,000	15, 0	25,000
	1 Vic. c. 66, s. 2	30 June 1837	40,000	...	40,000
			140,000	35,000	175,000
Limerick and Waterford	7 Geo. 4. c. 139, s. 49. 57	31 May 1826	350,00	250,000	600,000
Llanelly Railway and Dock	7 Geo. 4, c. 91, s. 3. 5	19 June 1828	14,000	6,000	20,000
	5 and 6 Will. 4, c. 96, s. 67	21 Aug. 1835	200,000	50,000	250,000
			214,000	56,000	270,000
Liverpool and Manchester	7 Geo. 4, c. 49, s. 75. 85	5 May 1826	510,000	127,500	637,500
	8 Geo. 4, c. 21, s. 3	12 April 1827	...	100,000	100,000
	10 Geo. 4, c. 35, s. 28	14 May 1829	127,500	...	127,500
	2 Will. 4, c. 46, s. 20	23 May 1832	...	200,000	200,000
	7 Will. 4, c. 27, s. 2	5 May 1837	...	400,000	400,000
			637,500	827,500	1,465,000
London and Birmingham	3 Will. 4, c. 36, s. 3. 237	6 May 1833	2,500,000	835,000	3,335,000
	5 Will. 4. c. 56, s. 115	3 July 1835	...	165,000	165,000
	1 Vic. c. 64, s. 2	30 June 1837	...	1,000,000	1,000,000
			2,500,0 0	2,000,000	4,500,000
London and Brighton	1 Vic. c. 119, s. 136. 160	15 July 1837	1,800,000	600,000	2,400,000
London and Croydon -	5 Will. 4, c. 10, s. 3. 190	12 June 1835	140,000	45,000	185,000
	6 and 7 Will. 4, c. 121, s. 6	14 July 1836	100,000	...	100,000
	1 Vic. c. 20, s. 34, 35	11 June 1838	160,000	130,000	290,000
			400,000	175,000	575,000
London and Greenwich	3 Will. 4, c. 46, s. 98. 99	17 May 1833	400,000	133,333	533,333
	7 Will. 4, c. 50, s. 2, 3	8 June 1837	150,000	50,000	200,000
			550,000	183,333	733,333
London and Southampton	4 and 5 Will. 4, c. 88, s. 3. 141	25 July 1834	1,000,000	330,000	1,330,000
	1 Vic. c. 71, s. 67. 74	30 June 1837	400,000	130,000	530,000
			1,400,000	460,000	1,860,000
London Grand Junction	6 & 7 Will. 4, c. 104, s. 3. 228	4 July 1836	600,000	200,000	800,000
Manchester and Birmingham	1 Vic. c. 69, s. 164. 189	30 June 1837	2,100,000	700,000	2,800,000
Manchester and Leeds	6 & 7 W. 4, c. 111, s. 170. 191	4 July 1836	1,300,000	433,0 0	1,733,000
Manchester and Oldham	7 Geo. 4, c. 99, s. 46. 55	26 May 1826	75,000	20,000	95,000
Manchester, Bolton, and Bury	1 and 2 Will. 4, c. 60, s. 12	23 Aug. 1831	204,000	...	204,000
	2 Will. 4, c. 59, s. 31	1 June 1832	...	46,000	46,000
	5 Will. 4, c. 30, s. 6	17 June 1835	250,000	...	250,000
	1 Vic. c 25, s. 2	11 June 1838	...	150,000	150,000
			454,000	196,000	650,000

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
Maryport and Carlisle	1 Vic. c. 101, s. 89.-111	12 July 1837	180,000	60,000	240,000
Midland Counties -	6 Will. 4, c. 78, s. 3. 246	21 June 1836	1,000,0 0	333,000	1,333,000
Monkland and Kirkintilloch	3 Will. 4, c. 114, s. 16	24 July 1833	20,000 additional	...	20,000
Nantle - -	8 Geo. 4, c. 3, s. 2	21 Mar. 1827	...	20,000 additional	20,000
Newcastle-upon-Tyne and Carlisle - -	10 Geo. 4, c. 72, s. 53. 61	22 May 1829	300,000	100,000	400,000
	2 Will. 4, c. 92, s. 3	23 June 1832	...	100,000	100,000
	5 Will. 4, c. 31, s. 6	17 June 1835	150,000	...	150,000
	1 Vic. c. 23, s. 2	11 June 1838	...	100,000	100,000
			450,000	300,000	750,000
Newcastle-upon-Tyne and North Shields -	6 Will. 4, c. 76, s. 60, 68	21 June 1836	120,000	40,000	160,000
Newtyle and Cupar Angus	5 and 6 Will. 4, c. 84, s. 38. 43	21 July 1835	15,200	5,000	20,200
	1 and 2 Vic. c. 61, s. 2	4 July 1838	15,000	...	15,000
			30,200	5,000	35,200
Newtyle and Glammiss	5 and 6 Will. 4, c. 92, s. 37. 42	30 July 1835	20,000	6,600	26,600
Northern and Eastern	6 and 7 Will. 4, c. 103, s. 3. 192	4 July 1836	1,200,000	400,000	1,600,000
North Midland -	6 and 7 Will. 4, c. 107, s. 3. 222	4 July 1836	1,500,000	500,000	2,000,000
Paisley and Renfrew -	5 and 6 Will. 4, c. 85, s. 43. 71	21 July 1835	23,000	10,000	33,000
Polloc and Govan -	11 Geo. 4, c. 62, s. 29. 38	29 May 1830	10,000	5,000	15,000
	1 and 2 Will. 4, c. 58, s. 16, 17	23 Aug. 1831	36,000	15,000	51,000
			46,000	20,000	66,000
Preston and Longridge	6 & 7 Will. 4, c. 122, s. 3. 128	14 July 1836	30,000	10,000	40,000
Preston and Wigan	1 Will. 4, c. 56, s. 70. 78	22 April 1831	250,000	83,000	333,000
Preston and Wyre -	5 Will. 4, c. 58, s. 3. 119	3 July 1835	130,000	40,000	170,000
Rutherglen - -	1 & 2 Will. 4, c. 35, s. 35. 59	2 Aug. 1831	15,000	5,000	20,000
St. Helen's and Runcorn Gap	11 Geo. 4, c. 61, s. 67. 75	29 May 1830	120,000	30,000	150,000
	4 Will. 4, c. 3, s. 2 -	26 Mar. 1834	...	40,000	40,000
	1 Vic. c. 21, s. 2 -	11 June 1838	30,000	...	30,000
			150,000	70,000	220,000
aundersfoot -	10 Geo. 4, c. 108, s. 42. 48	1 June 1829	17,500	8,000	25,500
heffield and Manchester	1 & 2 Will. 4, c. 59, s. 93. 101	23 Aug. 1831	530,000	176,000	706,000
heffield and Rotherham	6 & 7 Will. 4, c. 109, s. 67. 75	4 July 1836	100,000	30,000	130,000
heffield, Ashton-under-Lyne, and Manchester -	7 Will. 4, c. 21, s. 108. 130	5 May 1837	700,000	233,000	933,0 0
lamannan -	5 Will. 4, c. 55, s. 27. 32	3 July 1835	86,000	20,000	106,000
	1 Vic. c. 94, s. 14 -	3 July 1837	29,000	...	29,000
			115,000	20,000	135,000
outh Eastern -	6 Will. 4, c. 75, s. 3. 208	21 June 1836	1,400,000	450,000	1,850,000
tockton and Darlington	9 Geo. 4, c. 60, s. 22	23 May 1828	100,000 additional	...	100,000
tratford and Moreton	3 Will. 4, c. 70, s. 14 -	10 June 1833	...	10,000	10,000
aff Vale - -	6 Will. 4, c. 82, s. 3. 198	21 June 1836	300,000	100,000	400,000
aw Vale (Railway and Dock)	1 and 2 Vic. c. 27, s. 63. 85	11 June 1838	15,000	5,000	20,000
hames Haven -	6 & 7 Will. 4, c. 108, s. 3. 147	4 July 1836	450,000	150,000	600,000
ister - -	6 Will. 4, c. 33, s. 70. 77	19 May 1836	600,000	200,000	800,000

Name of Company.	Act.	Royal Assent.	Capital in Joint Stock.	By Loan.	Total.
			L.	L.	L.
Warrington and Newton	10 Geo. 4, c. 37, s. 52. 62	14 May 1829	53,000	20,000	73,000
	11 Geo. 4, c. 57, s. 9	29 May 1830	...	20,000	20,000
			53,000	40,000	93,000
Whitby and Pickering	3 Will. 4, c. 35, s. 3. 167	6 May 1833	80,000	25,000	105,000
	7 Will. 4, c. 25, s. 2	5 May 1837	30,000	...	30,000
			110,000	25,000	135,000
Wigan Branch -	11 Geo. 4, c. 56, s. 69. 77	29 May 1830	70,000	17,500	87,500
Wishaw and Coltness -	10 Geo. 4, c. 107, s. 30. 35	1 June 1829	60,000	20,000	80,000
York and North Midland	6 Will. 4, c. 81, s. 3. 179	21 June 1836	370,000	123,333	*493,333

* By 1 Vic. c. 68, the capital to be raised is limited to L.335,000.

Note.—Where the word " additional" occurs, the original Act passed previous to 1826.

Capital in joint stock,	- - -	L.41,610,814
Power to raise by loan,	- - -	16,177,630
	Total, -	L.57,788,444

INDEX.

U

ERRATA.

Page 18, *line* 6, *for* stations, *read* sections.

— 32, — 32, — $a=\frac{30h+h^2}{9}$, *read* $a=\frac{30h+2h^2}{9}$.

— 72, — 3, — above, *read* alone.

— 75, — 30, — put in, *read* are put in.

— 76, — 34, — very, *read* every.

— 99, — 34, — $\frac{1}{26}$, *read* $\frac{1}{16}$.

— 101, — 18, — $\frac{1}{26}$, *read* $\frac{1}{16}$.

— 130, — 2, — fresh, *read* flush.

— 130, *last line*, — tin, *read* tire.

In pages 130 and 131 the woodcuts are transposed,—Fig. 19 is Mr. Losh's wheel, and fig. 20 Mr. Stephenson's.

Page 133, *line* 25, *for* inner tire, *read* inner parts of the tire.

— 150, — 29, *after* seen, a full stop.

— 151, — 9, *for* ropes, *read* tubes.

— 201, — 1, — constitution, *read* construction.

— 259, — 2, — sufficiently, *read* efficiently.

— 343, — 11, — luxury or, *read* luxury in.

— 351, — 10, — invented, *read* adopted.

— 380, — 35, — by which, *read* through this.

— 382, — 19, — longer, *read* larger.

— 383, — 19, comma not after *downward*, but after *only*.

— 384, — 35, *for* dispenses, *read* done away.

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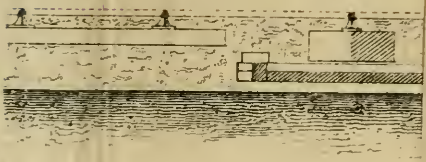
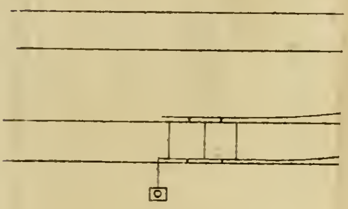
Fig. 8.





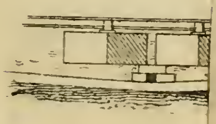


Fig. 4

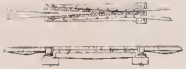


Fig 8

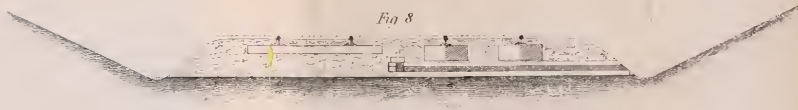


Fig 1.

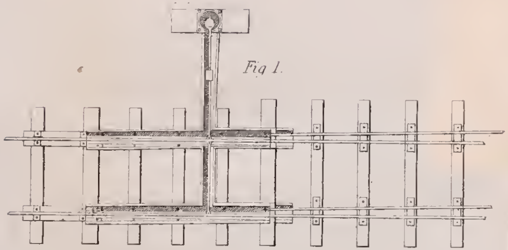


Fig 2

Fig 5.

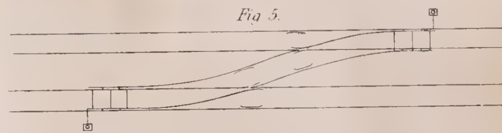


Fig. 6.

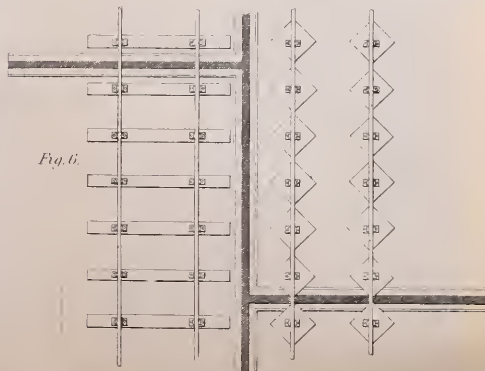


Fig 7.

Fig. 3.

PLATE CCCCXXI.

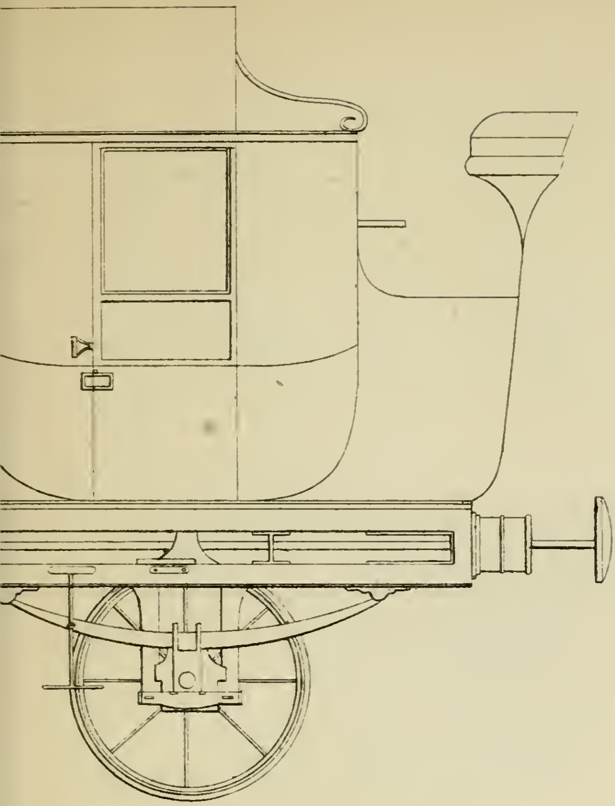
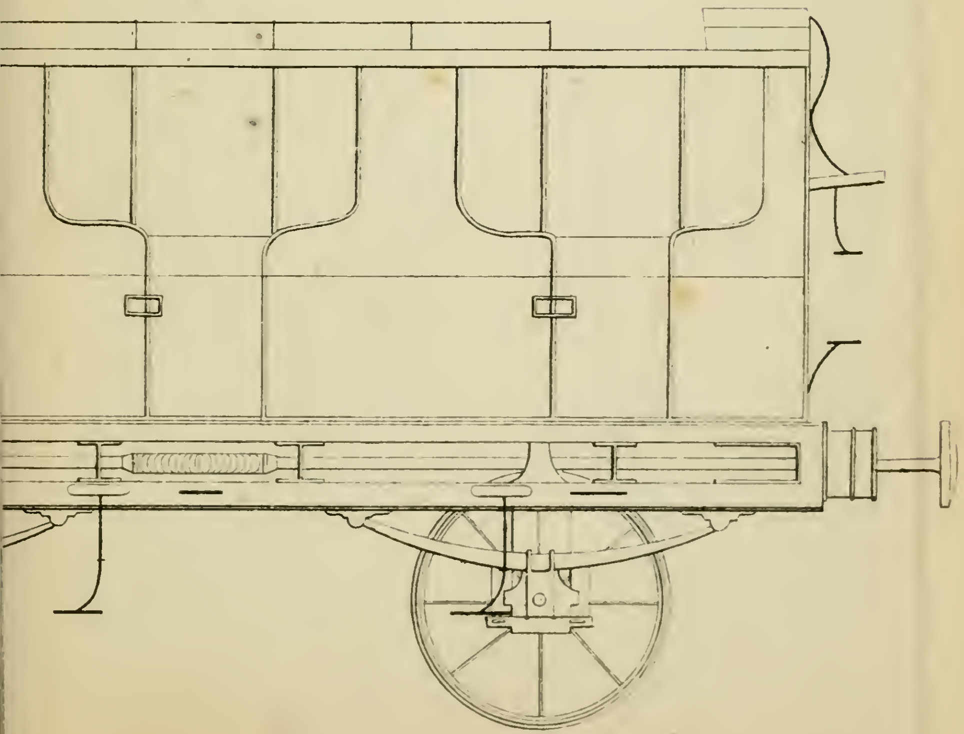


Fig. 2.



Geo. Aikman, Sculpt.

Fig 1

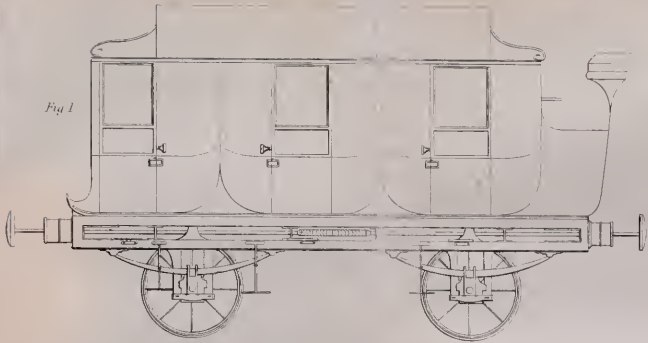


Fig 3.

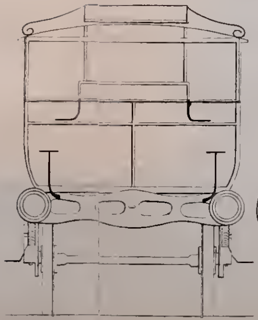


Fig 2

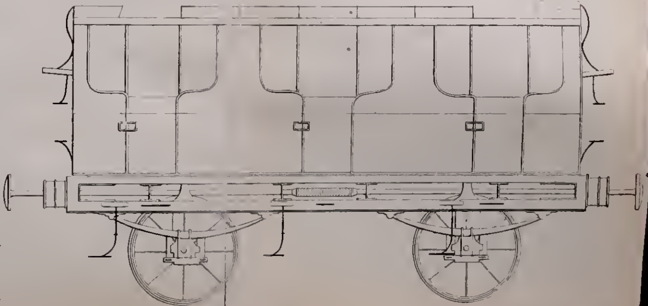
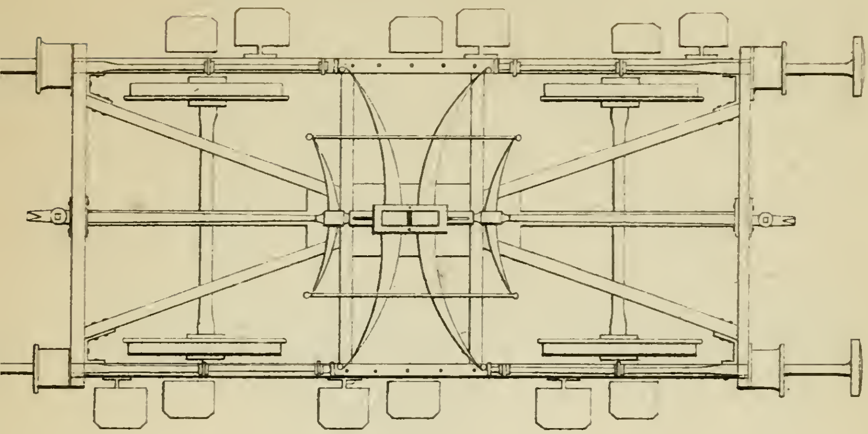


PLATE CCCCXXII.

Fig. 2.



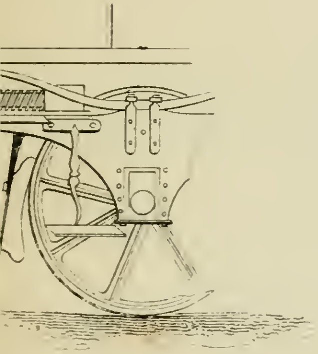
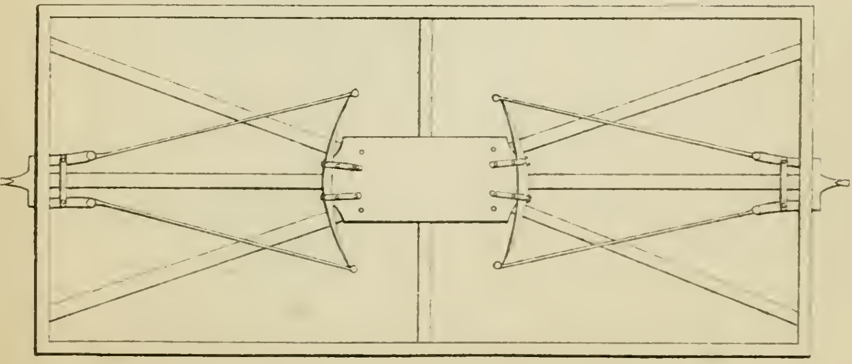


Fig. 4.



10 Feet

Geo. Aikman Sculp^t

Fig 1

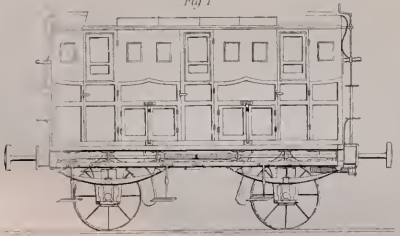


Fig 2

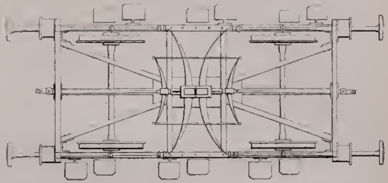


Fig 5

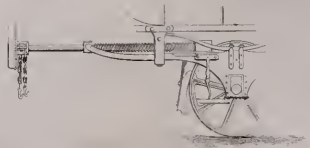
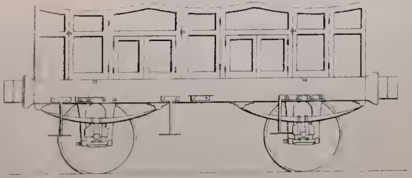


Fig 3



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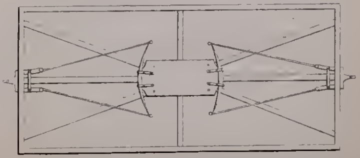


Scale of 10 Feet

Geo. Aikman Sculp^t

Fig. 2.

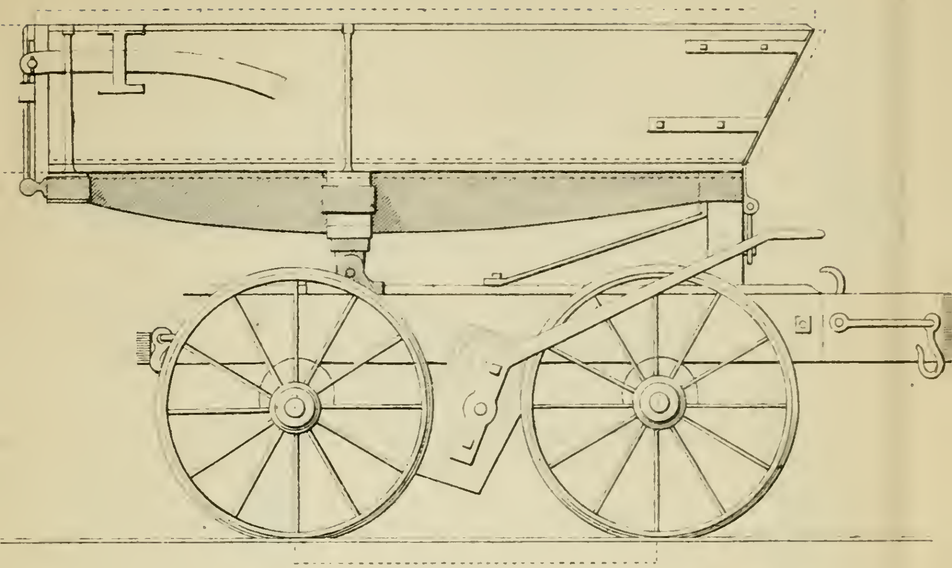


Fig. 4.

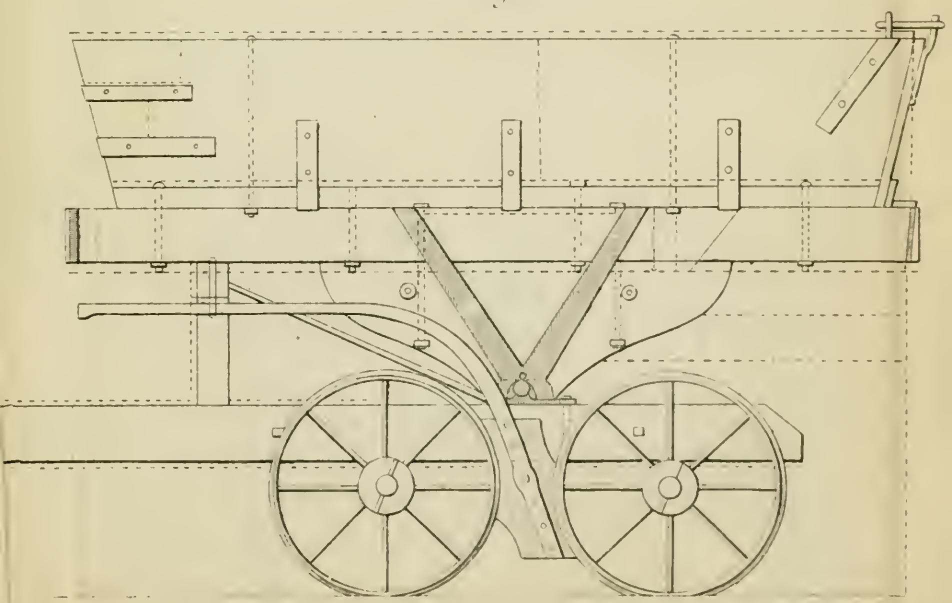


Fig 1

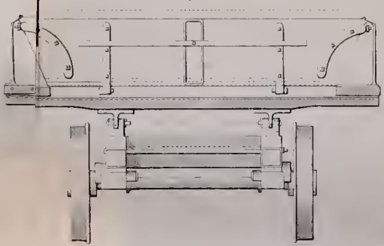


Fig. 2

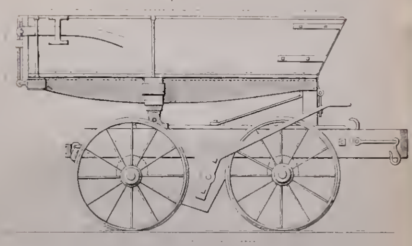
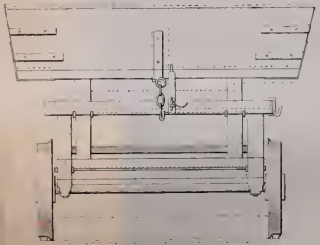


Fig 3



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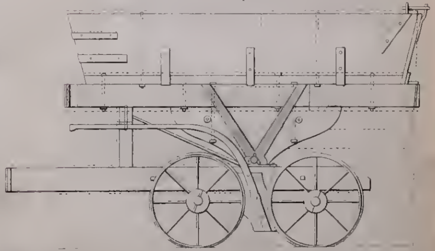

PLATE CCCCXXIV.

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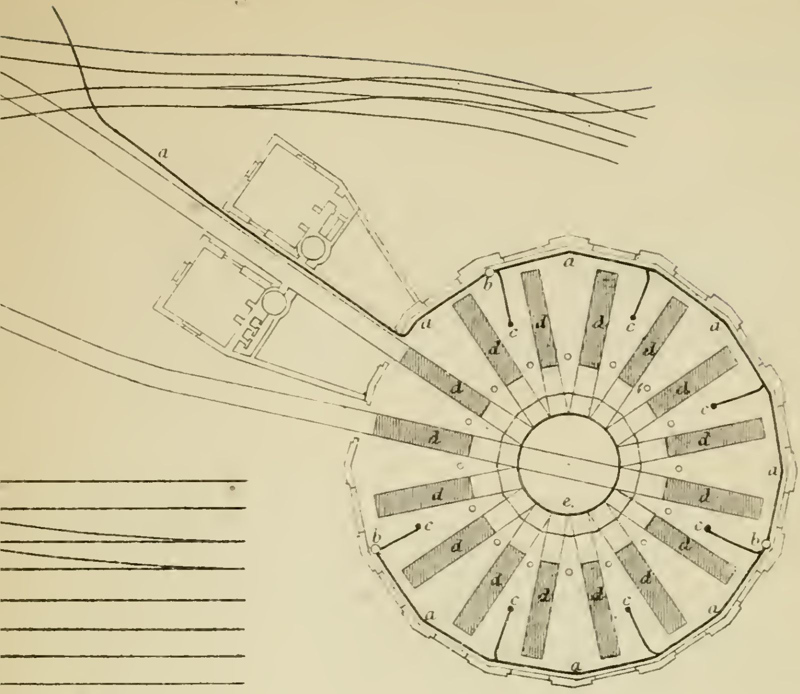


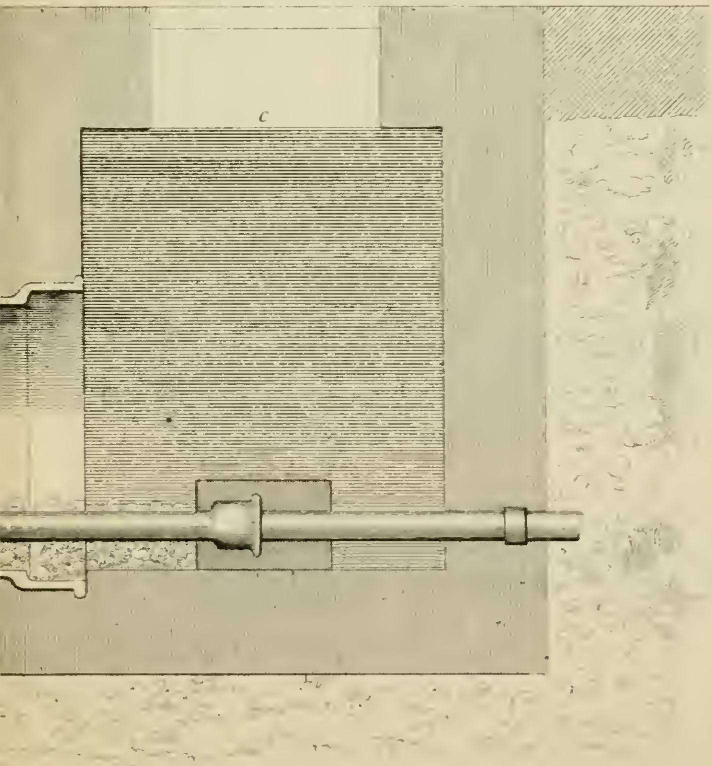


PLATE CCCCXXIV.

Fig 4

Fig 1.

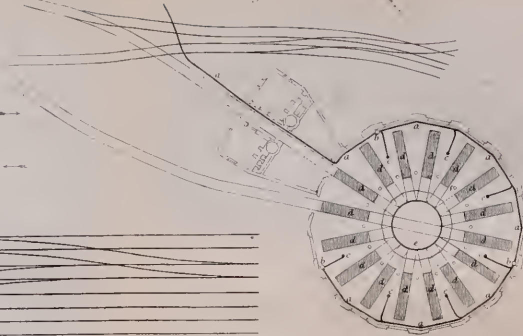


Fig 5

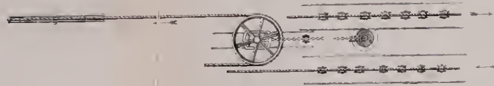


Fig. 3.

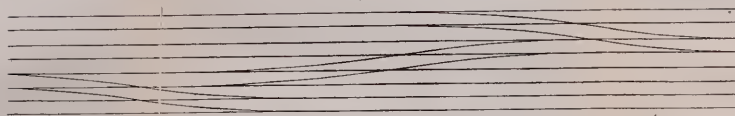


Fig. 2.

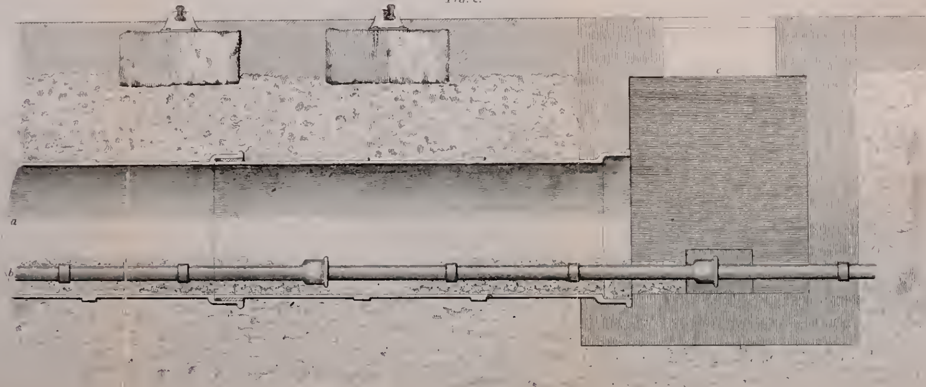
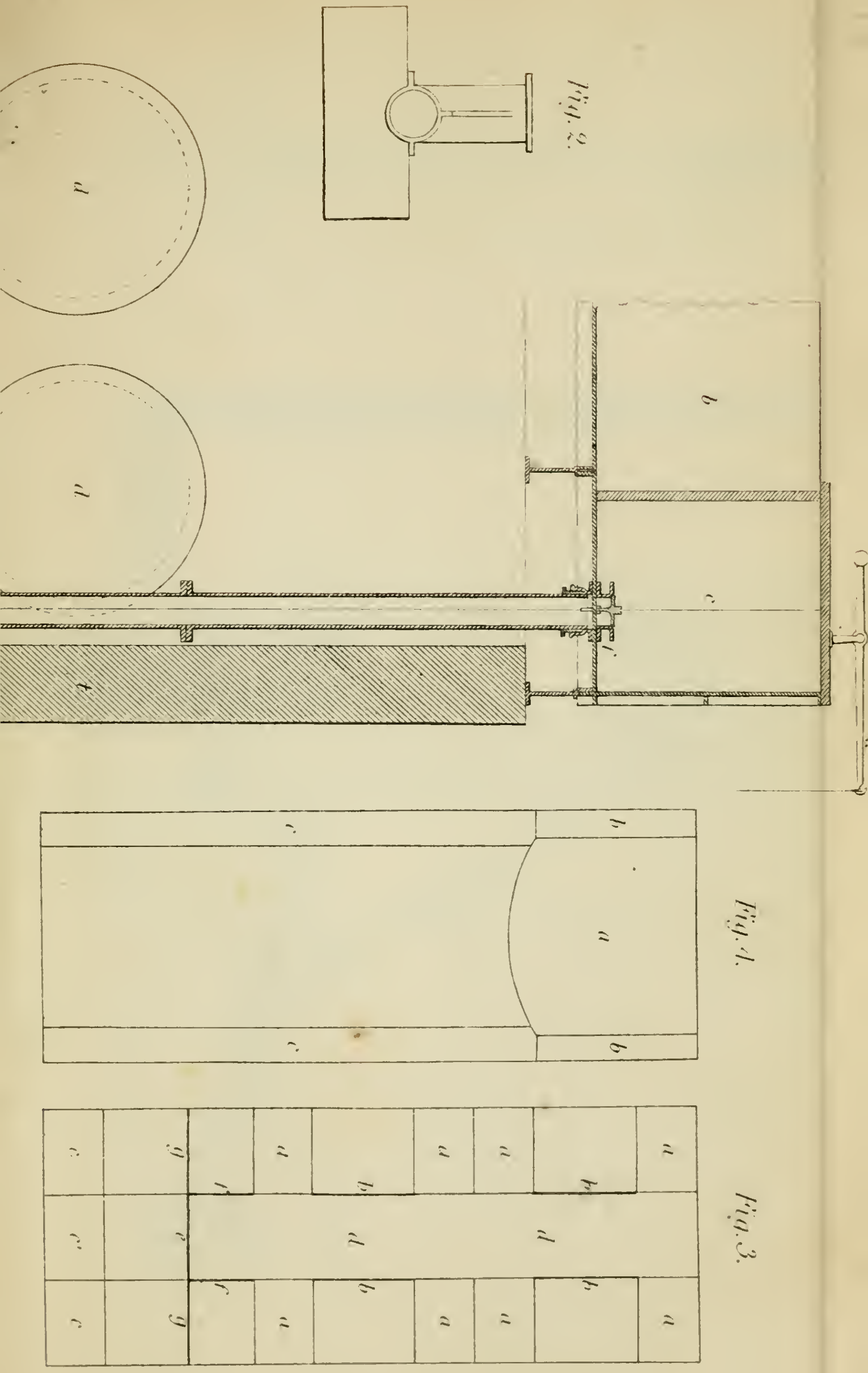
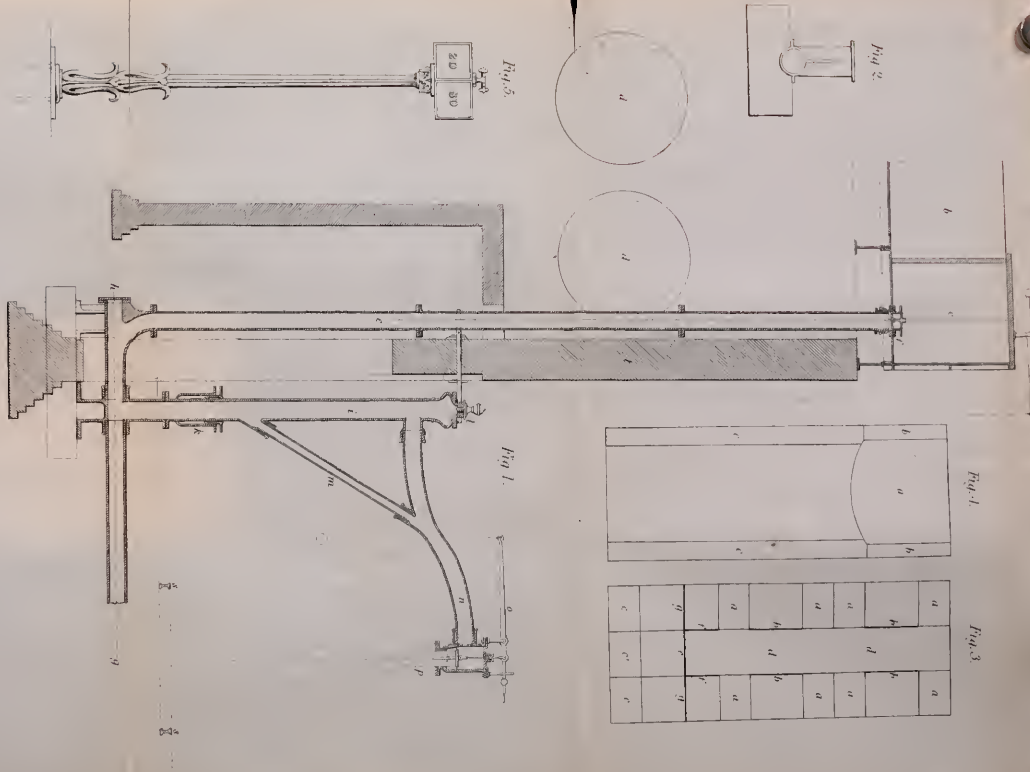


PLATE CCCCXXV.





Lt Lesaunt R.N. Delt

Fig. 3.

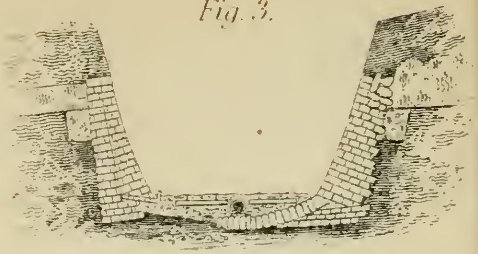


Fig. 5.

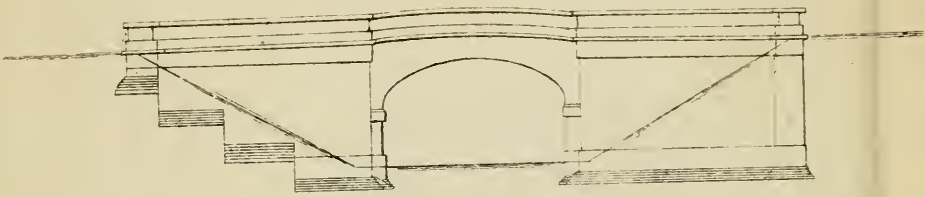
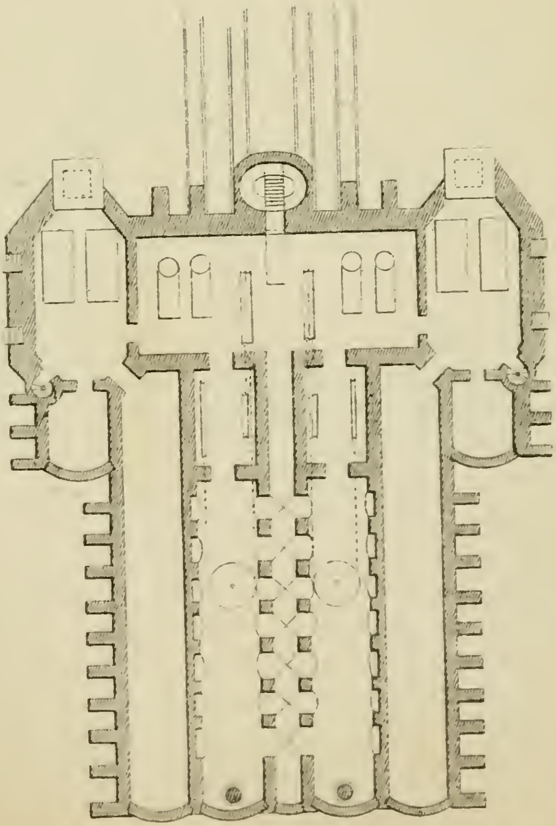


Fig. 6.



Geo Aikman Sculpt

Fig 2

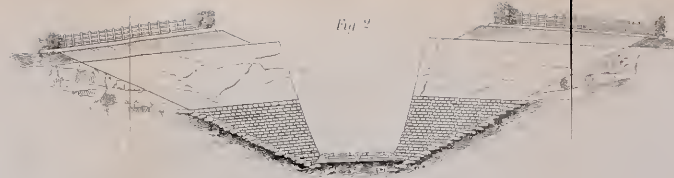


Fig 3

Fig. 4.

Fig 5

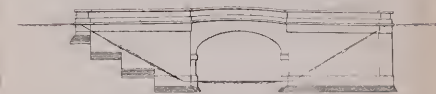


Fig. 1.

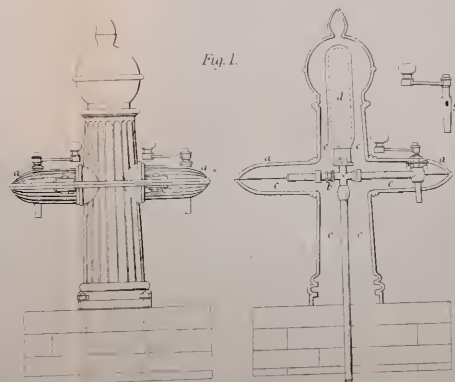
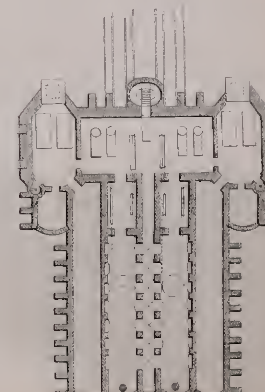


Fig. 6



man Sculp^t

PLATE CCCCXXVI

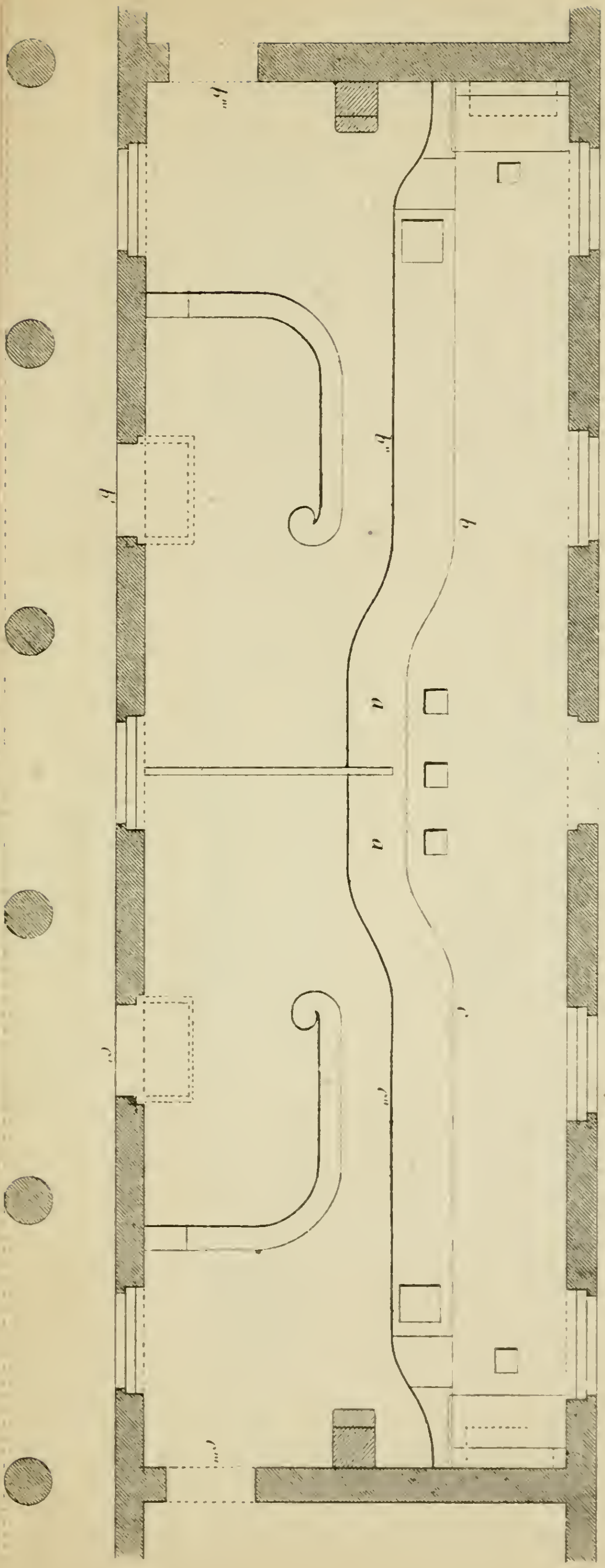


Fig. 3.

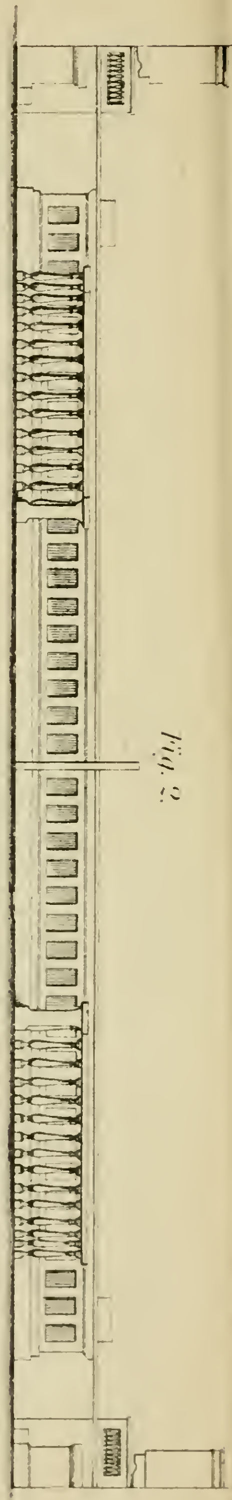


Fig. 2.

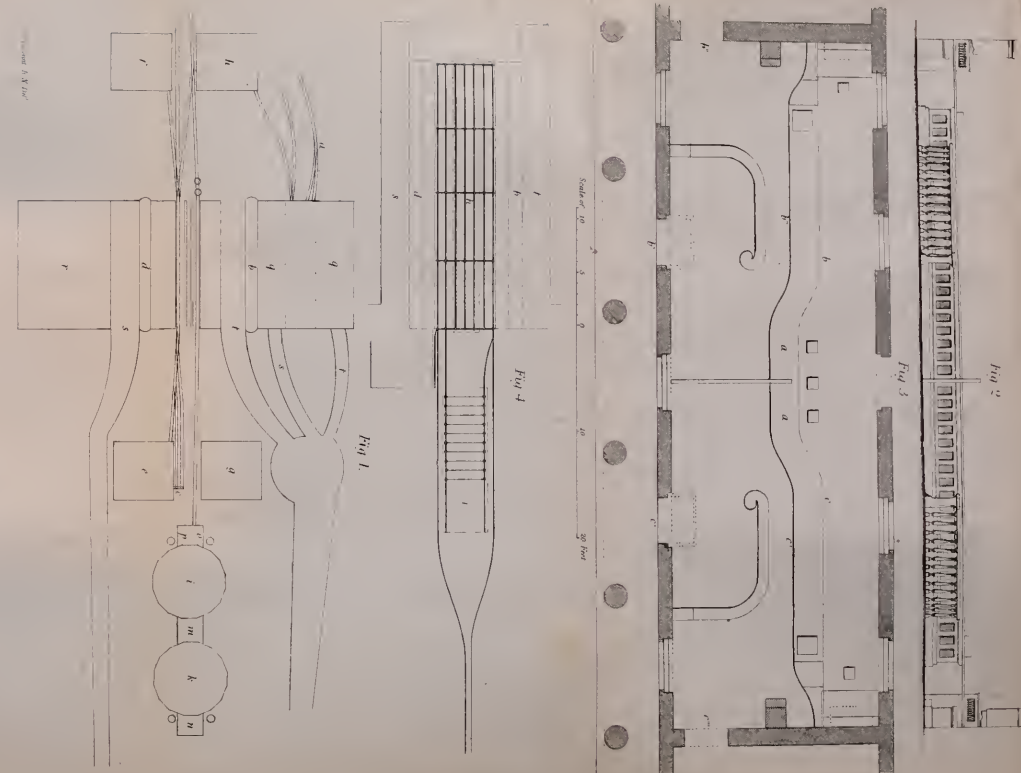


Fig 1.
Fig 2
Fig 3
Fig 4
Scale of 10 5 0 10 20 Feet

PLATE CCCCXXVIII.

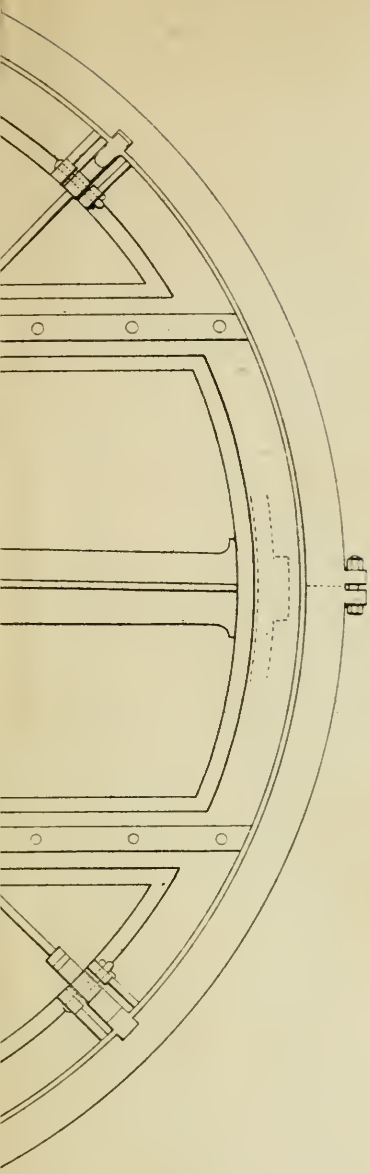


Fig. 3.

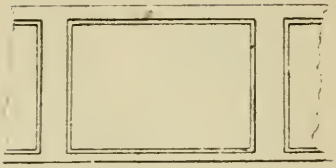


Fig. 4.

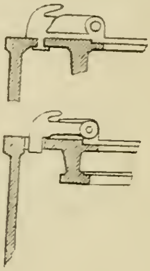
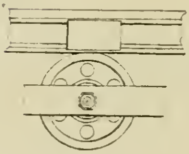


Fig 5.



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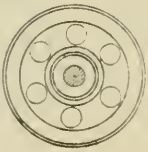

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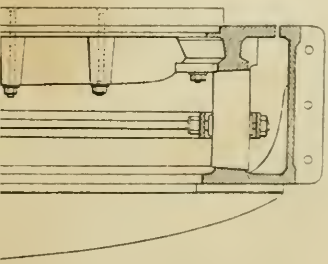

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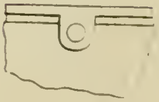
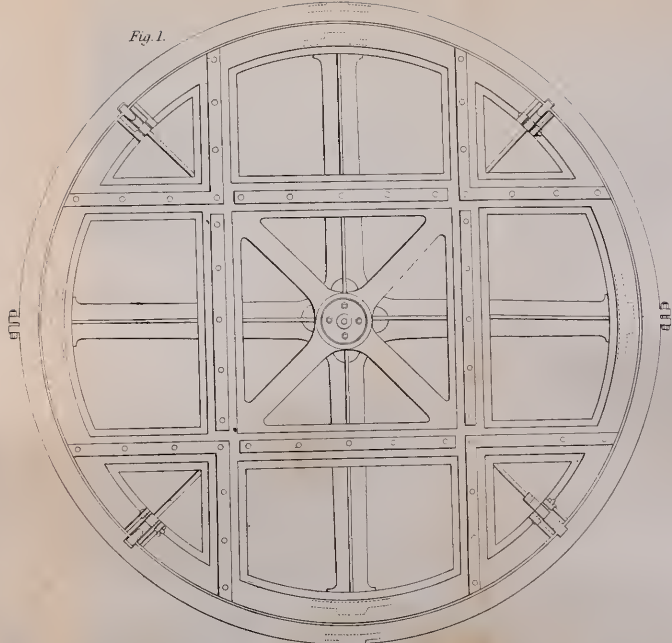


Fig. 1.



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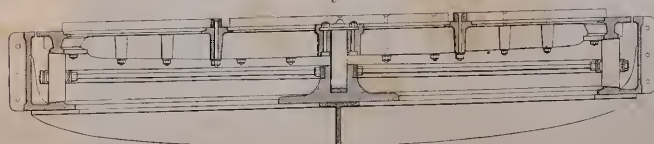


Fig. 3.

Fig. 4.

Fig. 5.

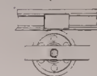
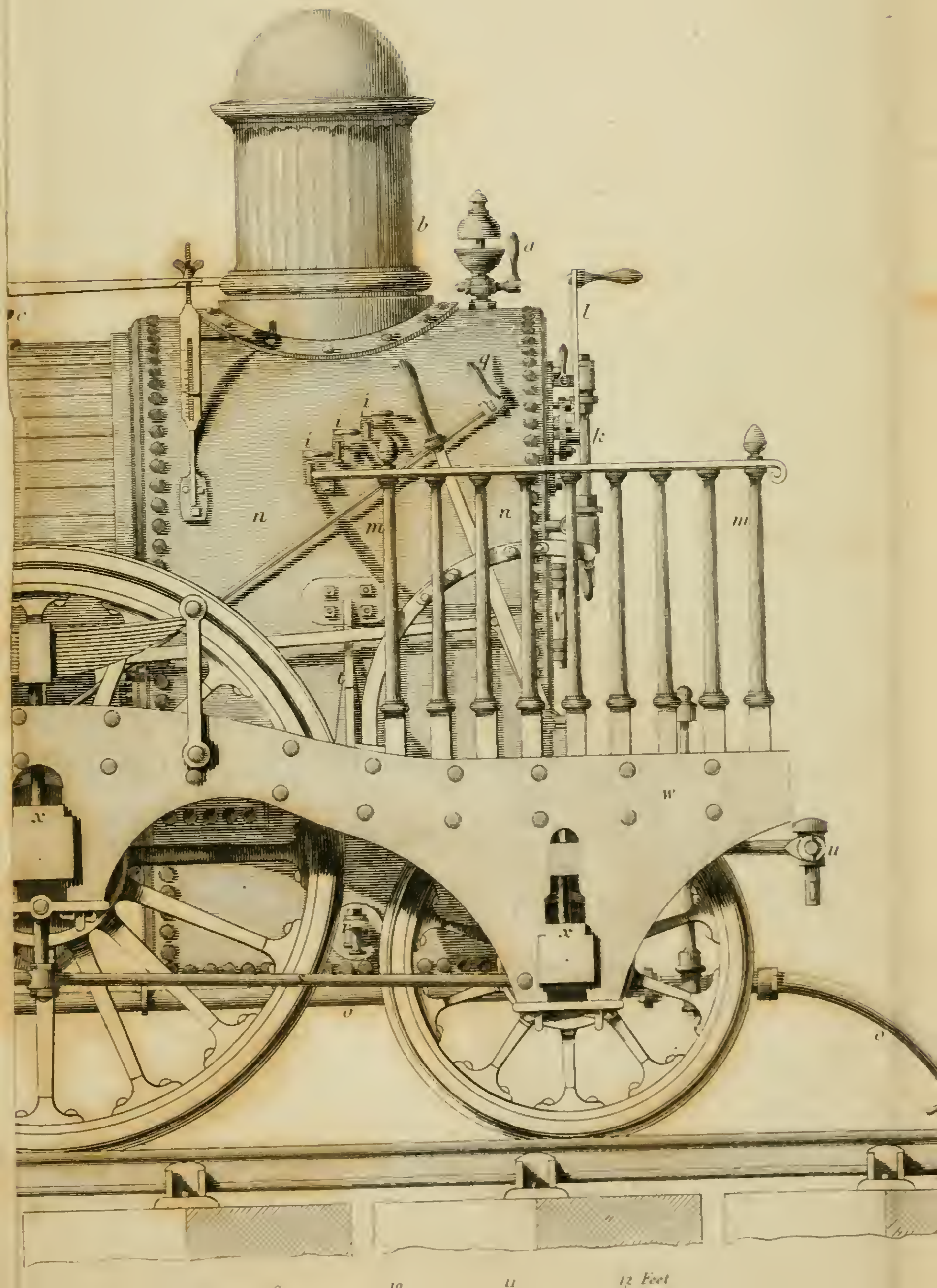


Fig. 6.

Fig. 7.

Fig. 8.

VE ENGINE.



ELEVATION OF A LOCOMOTIVE ENGINE.